Annual Report 1949

National Bureau of Standards

Miscellaneous Publication 198

UNITED STATES DEPARTMENT OF COMMERCE
Charles Sawyer, *Secretary*

NATIONAL BUREAU OF STANDARDS
E. U. Condon, *Director*

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of
Standards

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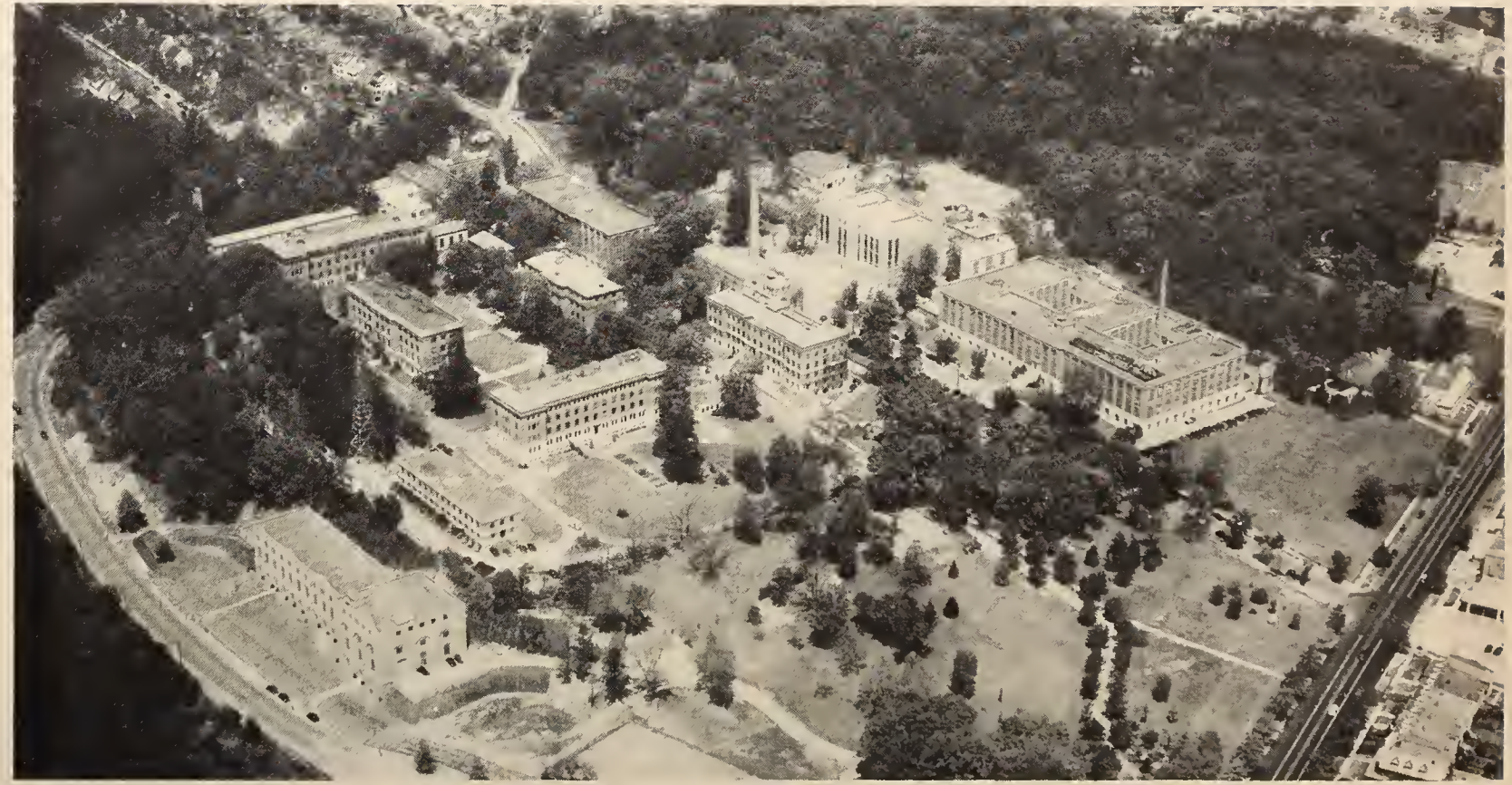

Aerial view of the National Bureau of Standards.

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1. General Review

As the principal agency of the Federal Government for fundamental research in physics, mathematics, chemistry, and engineering, the National Bureau of Standards carries on a large number and variety of projects in these fields. It acts as custodian of the national standards of physical measurement and conducts the necessary research leading to improvement in such standards and measurement methods. It investigates problems in basic science, undertakes major applied research and development programs, develops improved methods for testing materials and equipment, determines physical constants and properties of materials, develops specifications for Federal supplies, and serves in an advisory capacity on many scientific and technical matters in the physical sciences.

Most of the Bureau's work was conducted at its laboratories in Washington. Six materials testing stations, chiefly concerned with cement analysis, were maintained in Allentown, Pa.; Permanente, Calif.; Seattle, Wash.; Riverside, Calif.; Denver, Colo.; and San Francisco, Calif. Two proving grounds were in use during the year (one in Maryland, the other in New Jersey). A railway-scale test-car station was maintained in Clearing, Ill. Research in certain fields of applied mathematics was conducted at the Bureau's Institute for Numerical Analysis, Los Angeles, Calif. Radio propagation activities involved the maintenance of field stations at Sterling, Fort Belvoir, and Hybla Valley, Va.; Puunene and Palmyra Island, Territory of Hawaii; Guam; Trinidad, British West Indies; White Sands Proving Ground, Las Cruces, N. Mex., and Anchorage, Alaska. Eleven other radio propagation field stations were under contract to the Bureau. In addition, two transmitting stations were operated: WWV at Beltsville, Md., and WWVH in Hawaii.

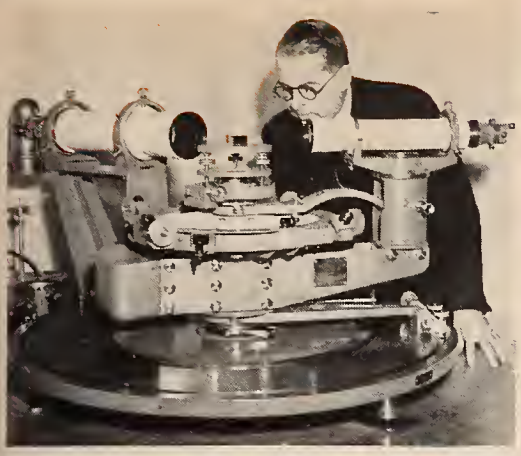
The research and development work of the Bureau is primarily of two kinds. There are, first, the investigations that result from the Bureau's responsibility for fundamental measurements in the physical sciences, the development and maintenance of primary standards in science and engineering, and the testing and calibration of standard measuring apparatus and reference standards. In these fields, research and development are mainly directed toward greater precision in measurements concerned with the Nation's fundamental scientific standards, physical constants, and properties

of substances and materials. At the same time, however, new standards and measurements of this general type must be investigated and developed as new fields of science open, such as atomic and nuclear physics, the higher frequencies in radio propagation, and the chemistry of high polymers. A second phase of research and development at the Bureau consists of large-scale specific projects undertaken either under direct congressional authorization or for other Government agencies. Examples of the former are the work in artificial radioactivity, building technology, and high polymers; examples of the latter include guided missiles, ordnance electronics, jet engines and fuels, electronic computing machines, numerical analysis, and many of the projects relating to aeronautics.

The following three activities of the Bureau—technical and consulting services, national cooperation, and international cooperation—stem directly or indirectly from the preceding functions and responsibilities of the Bureau. The results of the Bureau's investigations, combined with the knowledge of its specialists in some 100 fields within the physical sciences and mathematics, are at the disposal of the Government. Accordingly, extensive technical and consulting services are provided to other Government agencies. During the course of the year, every major agency of the Federal Government, hundreds of bureaus and offices, a large number of States, and many county and municipal governments called on the Bureau for technical aid.

Cooperation of a national nature is extended to scientific and technical societies, groups, and organizations, to industries, private laboratories, and universities. An important aspect of this cooperation has to do with scientific and technical standards, many of them related to products and equipment, safety problems, and codes. The Bureau cooperates with such groups for several reasons: the Government, as the largest single purchaser in the world, has a direct interest in this work; the Bureau is able to contribute certain types of information not available elsewhere; and the Bureau itself profits from the knowledge it gains of developments outside its own laboratories. International cooperation is based largely on the role of the Bureau as the technical spokesman for the United States on international agreements relating to the development and establishment of international scientific standards.

The scientific activities of the Bureau during the fiscal year 1949 were carried out through 13 scientific divisions concerned with electronics, applied mathematics, atomic and radiation physics, radio propagation, electricity and optics, metrology, heat and power, chemistry, mechanics, organic and fibrous materials, metallurgy, mineral products, and building technology. A fourteenth division was concerned with commodity standards and with the coordination of the Bureau's work for the Federal Specifications Board. The remainder of this report attempts to suggest the nature and scope of the Bureau's work through examples of typical projects. Only a small proportion of all projects can actually be covered in this way, but the topics discussed have been chosen as representative of the over-all program.



Left: this high-precision spectrometer determines the refractive index of transparent materials used by the Bureau in standardizing industrial refractometers. Right: a new precision camera calibrator recently developed by the Bureau is tested for accuracy (p. 8).

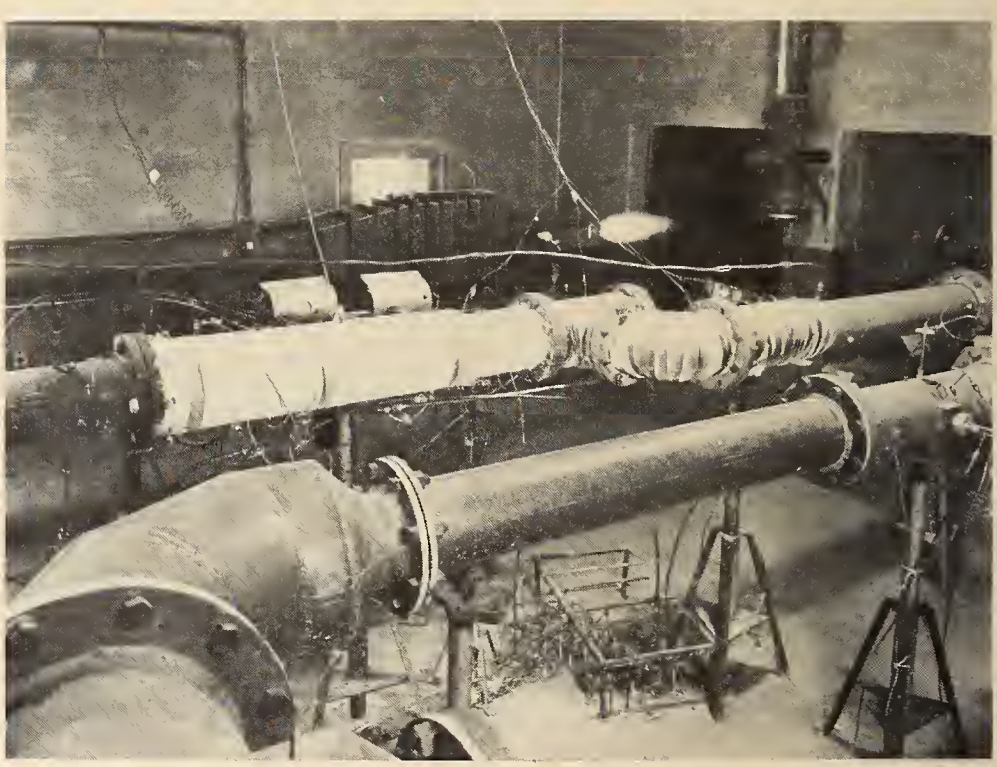
2. Electricity and Optics

The work in electricity and optics is for the most part closely connected with problems of measurement in these fields and relates to the establishment of units of measurement, the development of improved or new methods of measurement, the design of improved or new standard apparatus, the development of standards for issuance, and studies of the properties of materials.

The electrical work includes the establishment and maintenance of the units of resistance and voltage; their application in the development of standard apparatus for measuring inductance, capacitance, electric current, power, energy, magnetizing force, and magnetic induction; and the dissemination throughout the Nation of standard values of these quantities. The work in optical standards and measurements includes problems of luminous intensity and flux; spectrophotometry, color, transmittance, reflectance, opacity and gloss; refractive index, focal length and resolution of lenses, cameras, and other optical systems; and sensitivity and contrast of photographic emulsions. In recent years microcopying of documents to conserve space and to insure permanence of records has grown to such an extent that the development and maintenance of standards of quality for these materials has become important. The following projects illustrate the type of work carried forward or completed during the year.

Maintenance of the Standard Ohm

The unit of electrical resistance, the ohm, is defined in terms of the units of length and time and the permeability of free space. The measurement of resistance in terms of these units is very difficult and is carried out only for the purpose of calibrating standards of resistance for national standardizing



Recent developments in gas turbines and jet engines have given rise to urgent need for research on problems concerned with combustion, control of fuel supply, and measurement of the temperature, composition, and thermal properties of exhaust gases (p. 18). Above: general view of combustion research laboratory. Below: interior of the combustion room showing three burner channels for combustion research.

laboratories. These standards are then used for calibrating working standards submitted by industry and private laboratories.

Between measurements of the national standards in terms of length, time, and permeability, it has been assumed that they have remained constant. Heretofore there has been no way to check this assumption, for only relative values of the standards could be determined. However, as an outgrowth of a recent elaborate measurement of resistance at the Bureau in terms of length, time, and permeability, it has now been found practicable to make frequent tests of the national standards, thus insuring their stability with time. This is done by a method developed at the Bureau for the measurement of resistance in terms of a mutual inductor. The dimensions of the inductor can be measured from time to time, and any change in inductance can be calculated from the change in dimensions. Comparison of the standard resistors with the inductor reveals any change in the values of the standard resistors. This method is so accurate that changes in resistance of a few parts in a million can be detected.

Precision Electrothermic Voltmeter for Audio Frequencies

To meet the need for greater accuracy of measurement in the audio-frequency range, new equipment has been completed and installed, permitting measurements of audio-frequency voltage with an accuracy approaching one part in 10,000. The equipment makes use of an insulated thermoelement whose heater is in series with a resistance used as a multiplier to extend its voltage range. It incorporates a simple Lindeck potentiometer which provides precise measurements of the thermal electromotive force produced by the thermoelement (selected to have negligible frequency error), thus permitting calibration on direct voltage. Associated equipment for current measurements to 50 amperes over the same frequency range is being installed.

Improved Magnetic Permeameter

The development of an improved magnetic permeameter for magnetizing forces up to 300 oersteds has been completed. The instrument is absolute in principle—i. e., its constants are derived from its own dimensions so that calibration by reference to any other permeameter is not required. The new instrument, called the M H permeameter, has an accuracy at least comparable to that of the Burrows permeameter, which for many years has been the accepted standard, yet it is much simpler to operate. Moreover, it requires only a single specimen, whereas the Burrows permeameter requires duplicate specimens, one of which is used as an auxiliary. The new permeameter will be adopted as the standard instrument for magnetic testing at magnetizing forces up to 300 oersteds.

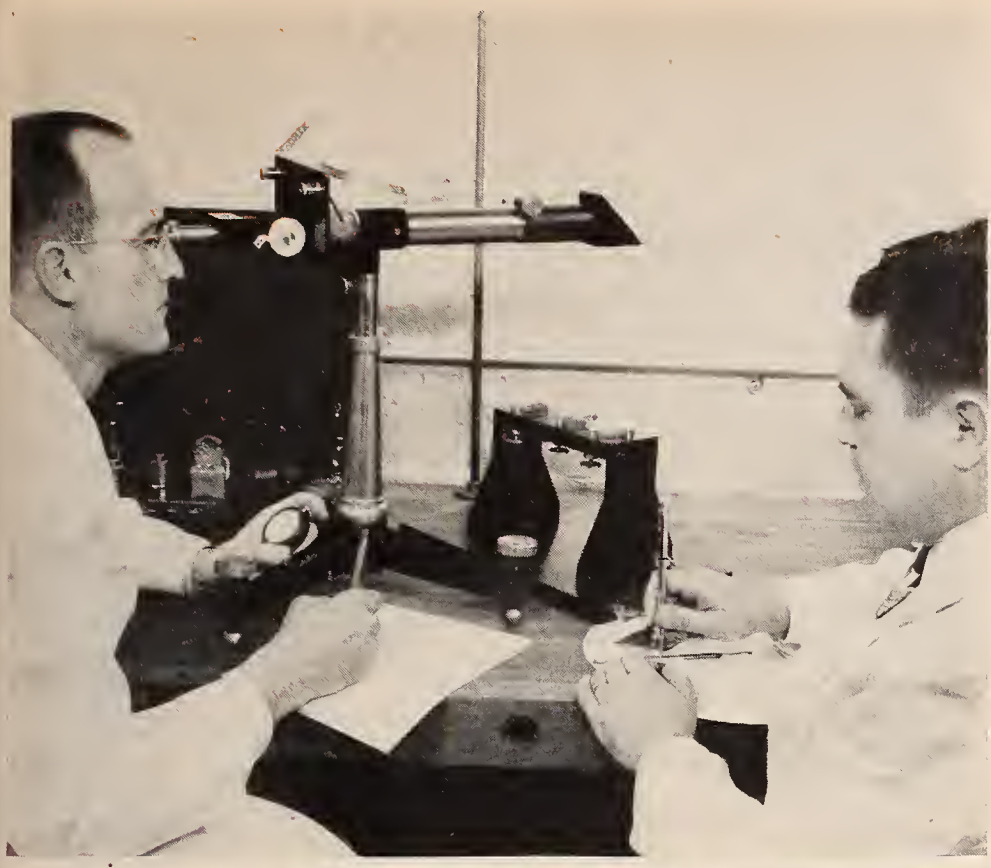
Surge-Voltage Measurements

Work continued on the project for improving front-of-wave surge-voltage measurements at intervals less than 1 microsecond. To this end, a large high-voltage electrode has been constructed to provide shielding and voltage grading of the space to be occupied by a resistance voltage divider. Measurements on a number of commercially available resistors revealed that they had excessive voltage coefficients and would not be suitable for this work. A promising resistor construction was therefore developed, consisting of a thin nichrome strip folded back and forth on itself with 1-mil insulation between folds. This resistor has a low voltage coefficient and constant effective resistance up to several megacycles. In experimental tests, the usual reverse-wound resistance cards (flat cards with one clockwise and one counterclockwise winding connected in parallel) were found to be properly shielded and to have satisfactory field grading when assembled in the shielded and graded space under the large high-voltage electrode.

New Calibration System for Camera Lenses

The method now in general use for designating the speed of a photographic lens is based entirely upon the ratio of the equivalent focal length of the lens to the diameter of the aperture. This ratio—known as the *f*-number—gives no consideration to the great differences in the useful light transmitted by various lenses. These difference are the result of absorption in the glasses of which the lens elements are made, or reflection and scattering at the surfaces. The introduction of reflection-reducing coatings has accentuated the inconsistencies of the present method to such an extent that for a given *f*-number the light transmitted by two lenses may differ almost by 100 percent. While this is a disadvantage in all photographic work, it is probably most costly to the motion-picture industry because of the large amount of film exposed each year and the additional expense of talent for retakes.

Recently the Bureau devised a new system of calibrating lenses which involves only a photometric measurement and eliminates the inconsistencies of the present system. The Society of Motion Picture Engineers has adopted the Bureau's calibration system, and the new method of lens marking will be used for professional motion picture cameras. Sixteen-millimeter cameras for amateurs and one type of still camera are now available commercially with the new system. It is expected that the new method of lens calibration will be embodied in specifications for still cameras and will be made generally available on all of the more expensive cameras.



Laboratory studies of the fundamental physical and clinical properties of dental materials are conducted at the Bureau (p. 13). Top: tendencies toward shrinkage in dental amalgam are determined by means of the dental interferometer. Lower left: to obtain data on materials and techniques, experimental dentures are processed under controlled conditions. Lower right: measurement of shrinkage in a plastic denture.

Testing of Photogrammetric Lenses

Photogrammetry, the science of making maps from airplane photographs (introduced shortly after World War I), is now one of the most important methods of map making, of great value for both military and civilian mapping purposes. Its applications include small-scale mapping of continental areas, large-scale mapping of small sites to aid in the placing of manufacturing establishments, mapping for tax purposes, and many other uses.

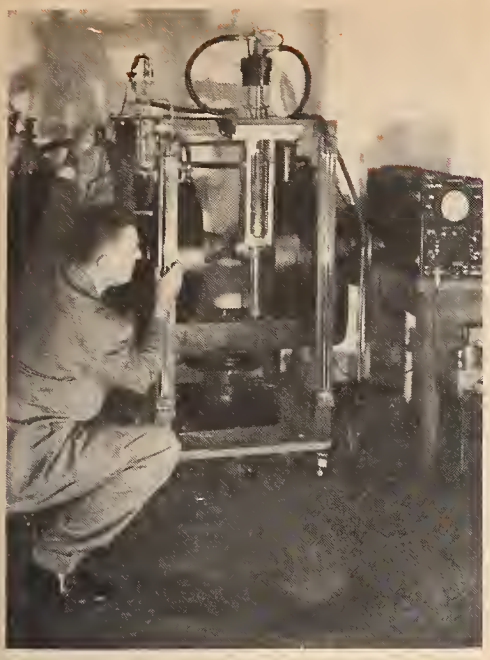
If maps made from airplane photographs are to be accurate, the errors of the camera lenses must be precisely determined and compensated for. The National Bureau of Standards is responsible for the necessary tests on the lenses and for certifying those which can be satisfactorily used for mapping. For many years these tests have been made with special testing equipment designed and constructed at the Bureau. However, this equipment tests the field of the lens along only one diameter at a time. Because of the greater volume of work required and the demand for increased accuracy, a new instrument has now been developed at the Bureau which enables the field of the lens to be tested simultaneously at 25 points located on two diameters. Tangential distortion, a source of error which has recently received increased attention, can be measured on this new apparatus.

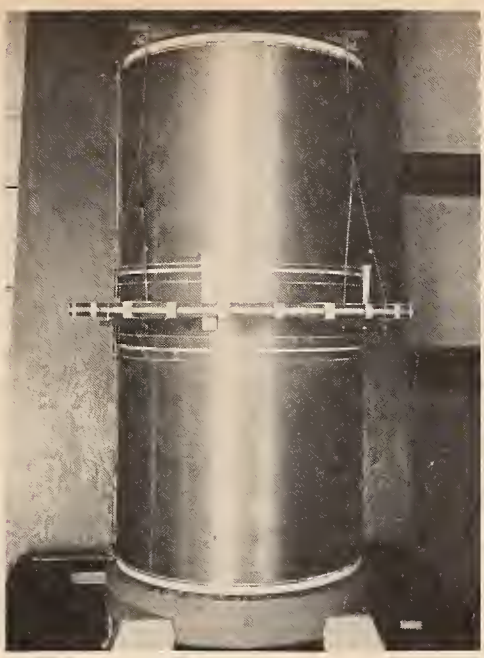
Standards for Calibration of Photoelectric Colorimeters

A number of complicated processes are employed in the refining of petroleum to produce gasoline, kerosine, and lubricating oils and greases. Measurements of the color of the product are used to follow the progress of these processes and also as a basis for the purchase and sale of petroleum products in various stages of refinement. To aid in this work, the petroleum industry, through ASTM Committee D–2, has been engaged since 1942 in the development of a photoelectric method for determining a color index for petroleum products. The Bureau has cooperated in this development by supplying permanent color standards, in the form of 2-inch squares of glass, to calibrate the photoelectric colorimeters. By use of these standards, all photoelectric colorimeters may be adjusted to read on the same basis so that the purchase and sale of partially refined petroleum may go forward on a fair and equitable basis without costly disputes.

Sensitometry of Diazo Papers

Diazo papers have largely replaced blueprint papers because they give a direct positive instead of a negative and because the processing is rapid and simple. The more popular of these papers is the "dry-developing" type, in which there is practically no shrinkage or change of the dimensions of the copy from that of the original. Because the variation in quality of diazo





Left: the velocity of second sound, a unique wavelike type of heat transfer occurring in helium II, was measured at temperatures near absolute zero in the Bureau's low-temperature laboratory (p. 17). Right: mutual inductor constructed at the Bureau for the absolute measurement of resistance in terms of length, time, and the permeability of free space (p. 3).

papers is large, it is important that purchase specifications be prepared so that the Government may obtain paper of suitable quality. Studies were therefore made on the sensitometric characteristics of the papers, such as speed, contrast, maximum density, and keeping qualities. The results of this work will be incorporated in a Federal specification.

Index of Refraction of New Infrared Materials

For the convenience of designers of optical systems to be used in the infrared region of the spectrum, the refractivity of truly mixed crystals of thallium iodide and thallium bromide was computed at wavelength intervals of 0.5 micron in the range from 1 to 39 microns. The values are based on numerous spectrometer measurements averaged for two prisms and then adjusted by the method of least squares to fit a Ketteler-Helmholtz dispersion equation. Check measurements on one of these crystals after a 12-month interval showed no change in index. This material, known as KRS5 during the war, is now being produced in a reasonably homogeneous state. It is the most transparent of all known optical materials in the wavelength region from 20 to 39 microns and is of importance in the construction of optical systems to transmit infrared energy.

3. Metrology

Problems of measurement, instrumentation, and standardization, involving the basic concepts of length, mass, time, capacity, and density, constituted the greater part of the work in this area of the Bureau's work. Other activities included a new and basic reproduction of the standard meter, investigations of the viscosity and flow of gases, research on dental materials, standardization of screw threads, boiler and turbine research, investigation of a proposed new method of weighing railway cars, standardization of geodetic tapes, research on the thermal expansivity of solid material, and development of greater accuracy in the calibration of gage blocks.

The Standard Meter

In 1893 Michelson measured the International Prototype Meter in terms of the wavelengths of the red radiations of cadmium. Others repeated the work. During the past year the same radiation was used at the Bureau as a standard to rule a meter interval on a platinum-iridium bar. The interval ruled agrees with the interval on the International Prototype Meter within a fraction of a wavelength (approximately 0.2 micron). This achievement is about 10 times more accurate than are the ruled intervals on our National Prototypes. Of equal importance is the fact that this research shows that the national and international platinum-iridium standards have not drifted from their original lengths.

Unification of Screw Thread Standards

On November 18, 1948, delegates and representatives from Government and industry of Canada, the United Kingdom, and the United States met at the National Bureau of Standards to sign an accord on unification of the American and British standard systems of screw threads. The accord, representing the culmination of 30 years of effort among the three nations, affirms the unification represented in revised publications of the Interdepartmental Screw Thread Committee of the United States of America and of the British Standards Institution, the Canadian Standards Association, and the American Standards Association. These documents fulfill all the requirements for general interchangeability of threaded products made in the three countries. Not only is the accord of major significance in expanding and facilitating commerce among the cooperating nations, but it also is an important step toward the further development and extension of unifying standards in other fields of engineering practice. In June 1949, the International Organization for Standardization, meeting in Paris, recommended that all member nations adopt the unified thread form for metric as well as for the usual types of screws.

In the United States, Subcommittee No. 1 of the A. S. A. Sectional Committee was charged with the revision of A. S. A. B1.1–1935, American Standard Screw Threads, and with embodying therein the Unified Screw Threads. This task was accomplished with the active cooperation of the

Declaration of Accord

with respect to the

Unification of Screw Threads

It is hereby declared that the undersigned, representatives of their Government and Industry Bodies, charged with the development of standards for screw threads, Agree that the standards for the Unified Screw Threads given in the publications of the Committees of the British Standards Institution, Canadian Standards Association, American Standards Association and of the Interdepartmental Screw Thread Committee fulfill all of the basic requirements for general interchangeability of threaded products made in accordance with any of these standards.

The Bodies noted above will maintain continuous cooperation in the further development and extension of these standards.

Signed in Washington, D. C., this 18th day of November, 1948, at the National Bureau of Standards of the United States.

H. D. Howe.	Ministry of Trade and Commerce, Dominion of Canada
J. Bellows	Canadian Standards Association
T. R. B. Sanders.	Ministry of Supply, United Kingdom
Percy Lloyd	British Standards Institution
Ernest Smith	Representative of British Industry
E. U. Condon	National Bureau of Standards U. S. Department of Commerce Interdepartmental Screw Thread Committee
Fred P. Peterson	American Standards Association The American Society of Mechanical Engineers Society of Automotive Engineers
William L. Batt	Sponsors Council of United States and United Kingdom on the Unification of Screw Threads

Interdepartmental Screw Thread Committee and the National Bureau of Standards. The Sectional Committee, organized under the procedure of the American Standards Association, is sponsored by the American Society of Mechanical Engineers and the Society of Automotive Engineers. The Unified Standards will be made effective in the departments of the U. S. Government by inclusion in the next revision of National Bureau of Standards Handbook 28, *Screw Thread Standards for Federal Services.* In the United Kingdom, the draft of the Provisional British Standard Unified Threads was prepared by the British Standards Institution in conjunction with the Inter-Services Technical Panel. The Canadians, with extensive commercial ties to both the United Kingdom and the United States, participated in the joint conferences and agreed to accept the standards developed by the British and Americans.

In the past, international trade in goods of all kinds has been seriously handicapped by the lack of interchangeability of screw thread parts. This has required the manufacturing nation also to supply and distribute such parts along with the equipment it wishes to market in a foreign area. Furthermore, the question of the availability of such parts has acted as a psychological deterrent to purchasers of products from other nations. These limitations on the international commerce of Canada, the United Kingdom, and the United States will gradually disappear as the unified standards are acted upon by the industries of the three nations in the ensuing years.

During the first World War, the experience of the allied American and British armed forces revealed that the lack of interchangeability of American and British screw threads was a serious problem. In World War II, the high degree of mechanization of all military forces made the problem even more serious than it had been. American industry was required to supply the British with a large volume of war equipment threaded to the British specification. This not only led to considerable delay but was economically disadvantageous. At the same time, American military forces based in England and using equipment with American threads found difficulties in making necessary replacements.

Since 1918, the National Bureau of Standards has taken the lead in the development of test methods and standards for screw threads. Largely as a result of the Bureau's efforts, the Unified Screw Thread Standard was ultimately formulated and agreed upon in five major and several informal conferences of representatives of the countries concerned. The present accord calls for a continuance of future cooperation in the field of screw thread standardization. Such cooperation has two aspects: first, the extension of the unification to the other English-speaking nations (all of which use the English system of measurement in manufacture) and, second, the continued development of standards, which must keep pace with improvements in materials and methods of production and inspection developed in industry. The reduction of the varieties of fasteners is one of the possibilities which further studies of standards and simplification may yield.

Dental Materials

Dental cements have never been satisfactory when mixed by the usual methods in the humidity and high temperature prevailing in the Tropics. They do not set properly and cannot be finished with a surface to match the teeth. Generally they stain and disintegrate in a few weeks or months. Recently techniques have been developed at the Bureau which permit these cements to be mixed in tropical surroundings with very little more difficulty than the provision of cold water as a cooling medium. A special container is used. A patent application, with rights to the Government, is being filed to cover this development.

Investigation of the fundamental principles involved in the polymerization of acrylic resins—used in making dentures and dental restorations—has continued. Data have been obtained on the effect that temperature, pressure, rate of curing, presence of impurities, and mold surfaces have on the properties of the cured resin. These data provide explanations for many of the difficulties—such as "open bite," shrinkage in repair, incomplete curing, premature polymerization, and discoloration—that have been encountered in the preparation of dentures and restorations.

The recent commercial development of a method for processing certain acrylic resins which may be cured at low temperatures has led to the widespread use of these resins in dentistry as restorative materials. Fundamental data on the physical and chemical properties and the curing characteristics of these resins have been obtained. As a result, considerable progress has been made in the development of satisfactory clinical techniques for using these materials.

Viscosity and Flow of Gases

The viscosity, pressure, temperature, and flow relations for fuel and other gases which are moved in pipelines are being investigated at the request of the U. S. Bureau of Mines and other interested organizations. These data are necessary in designing pipeline installations, in judging their efficiency, and in locating defects in lines now in operation.

4. Heat and Power

To provide a fundamental basis for precise measurements of heat and power, the Bureau has established and maintains a scale of temperature from the lowest obtainable to the highest temperatures of incandescent bodies and flames. Instruments are certified for the measurement of temperatures in this range on the International and Kelvin scales. From the measurement of temperature alone, the work broadens to include the determination of quantities of heat by calorimetry in temperature regions extending over a large part of the scale. Coordinate with the calorimetry is a study of the thermodynamic properties of solids, liquids, and gases. From these basic fields of research, the work branches into engineering

applications to automotive and aircraft engines. One branch extends into the fundamentals of combustion, with applications to gas turbines, jet engines, and jet propulsion. Another branch covers lubrication problems that arise not only in automotive engines but in all mechanical devices.

The Bureau is also responsible for determining and maintaining standards of viscosity and for certifying the viscosities of fluids used for calibrating viscometers. It maintains standards for the metering and carburetion of liquid fuels in internal combustion engines, and for the determination of the octane and cetane numbers of automotive, aviation, and Diesel engine fuels. Research is conducted to increase the accuracy of these standards and to develop improved measuring instruments and apparatus. Thermal properties of pure substances and commercial materials are determined, upon requests from other Government agencies, either by direct experiment or by calculation from the fundamental atomic and molecular properties of the substances, and published data on thermal properties are critically reviewed and compiled.

Thermometry

On January 1, 1949, the National Bureau of Standards began using the definitions of the International Temperature Scale of 1948 both in its own research program and in calibrating instruments for other scientific and industrial purposes. Based on a draft prepared by members of the Bureau staff, the new scale was adopted at Paris by the Ninth General Conference on Weights and Measures in October 1948, and the official text was approved for publication before the end of the year. This is the first revision of the International Temperature Scale since its adoption 21 years ago. The experimental procedures by which the scale is realized are substantially unchanged, but certain refinements, based upon experience, have been incorporated to make the scale more uniform and reproducible.

The same fixed points, with one slight modification, are specified in the 1948 scale, and the laboratory procedures for obtaining temperatures between fixed points are essentially the same as those previously used. Only two revisions in the definition of the scale result in appreciable changes in the numerical values assigned to measured temperatures. One of these is the change in the value for the silver point from 960.5° to 960.8° C, which affects temperatures measured with the standard thermocouple. Thus, in the range between 630° and 1,063° C, numerical values of temperature are higher than on the 1927 scale, the maximum difference being about 0.4 degree near 800° C. Likewise, the adoption of a new value (1.438 cm-deg) for the constant c_2 in the radiation formulas changes all temperatures above the gold point (1,063° C). In the new scale, Planck's radiation formula is specified instead of Wien's for calculating temperatures above the gold point as observed with an optical pyrometer. Since Planck's law is consistent with the thermodynamic scale even at high temperatures, this change

removes the upper limit to the scale formerly imposed by the use of Wien's law.

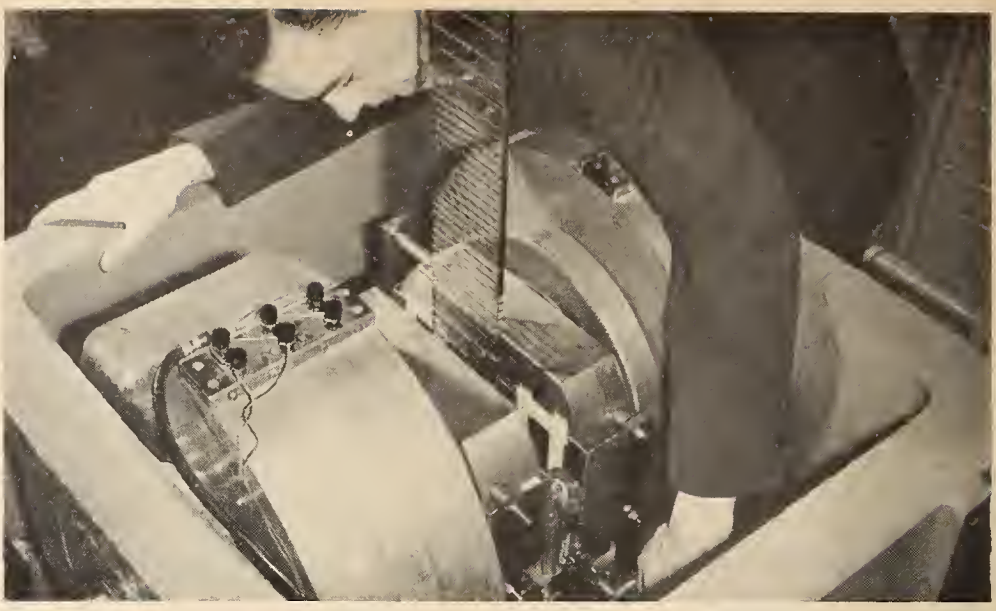
Thermometry at very low temperatures has recently assumed a new importance because of the great increase in the number of academic, government, and industrial laboratories that are engaged in basic research in low-temperature physics. At present, temperatures are usually determined with hydrogen or helium vapor-pressure thermometers. However, these thermometers cover only limited temperature ranges, leaving a hiatus between 5° and 10° K, and are entirely unsuitable for many applications, such as calorimetry. For this reason, the Bureau has undertaken the development of sensitive and stable resistance thermometers for use between 1° and 50° K. The successful conclusion of this project should result in instruments that could be calibrated on the thermodynamic temperature scale and used in any laboratory, thus providing an accurate and uniform low-temperature scale. The principal advances that have so far been made are the improvement of the stability of a number of alloy thermometers by a new method of construction, the construction and test of silicon thermometers of very high sensitivity, and the design of a gas thermometer to be used for the basic calibration of secondary standards.

Thermodynamics

The determination, critical evaluation, and formulation of data on the basic thermal properties of gases, liquids, and solids were continued. Current efforts are concentrated on data requested by other Government laboratories, which are also needed by industry.

As an example, recent advances in jet propulsion and high-speed flight have emphasized the importance of more accurate thermal data for gases and gas mixtures that occur in wind tunnels and jet engines, such as air, nitrogen, oxygen, carbon dioxide, water vapor, carbon monoxide, hydrogen, etc. With the cooperation of the National Advisory Committee for Aeronautics, a series of tables of thermal properties of gases is being compiled. The compilations present such properties as specific heat, enthalpy, entropy, compressibility factor, density, vapor pressure, sound velocity, viscosity, thermal conductivity, and Prandtl number. The tables are based both on published and unpublished data and on calculations and experiments carried out at the Bureau. Their range extends from low pressures up to 100 atmospheres, and from low temperatures, such as occur in high-speed wind tunnels, to 3,000° K, a temperature encountered in jet engines. Approximately 20 such tabulations, each covering one or more properties of a single gas, are nearly complete.

To obtain data for these tables, the vapor pressure of oxygen was measured with high accuracy from the triple point (54.363° K) to the critical point (154.78° K). The specific heat of carbon dioxide was also determined for several low pressures at 0° C by means of the vapor flow calorimeter developed at the Bureau. Apparatus is now being constructed for



Magnet assembly used by the Bureau's atomic physics laboratory in the determination of the absolute value of the magnetic moment of the proton (p. 19).

measurements of the thermal conductivity of gases at temperatures up to 500° C and pressures up to 100 atmospheres.

Although the thermal properties of gases at very high temperatures (above 1,500° K) are very difficult to measure, they may be calculated by reliable methods from spectroscopic data. Studies of the spectra of water-vapor and carbon dioxide and of the general theory of the structure of such triatomic molecules were pursued in order to increase the accuracy with which the thermal properties of these gases may be calculated at the high temperatures of current interest. The calculations will be checked against experimental values at lower temperatures. In the course of the spectroscopic work, some 5,000 spectral lines were identified and classified in the absorption of the sun's radiation by the water vapor in the earth's atmosphere. The dissociation of molecular gases into atoms and molecular fragments also has a considerable effect on the thermal properties at high temperatures; calculations of these effects were made and are included in the tabulations.

To provide the Government with necessary engineering data, the enthalpies of beryllium and sodium were accurately measured between 0° and 900° C. The specific heat and other thermodynamic properties of these elements were also derived. Additional basic calorimetric data, obtained for the Office of Rubber Reserve and the Government's synthetic rubber program, yielded values for the heat of polymerization of butadiene, of use in the recently developed method of low-temperature polymerization for making synthetic rubber. Determinations were also made of heats of copolymerization of butadiene and styrene in a number of commercial and

experimental synthetic rubbers, including GR-S. In addition to their industrial importance, these data provide information concerning the basic structure of high polymers.

Low-Temperature Physics

The phenomenon of superconductivity is in many respects the most challenging field of research in low-temperature physics. As a consequence of the complete disappearance of electrical resistance and the appearance of perfect diamagnetism at temperatures near absolute zero, spectacular effects are obtained which, when interpreted theoretically, give promise of a basic insight into some of the fundamental properties of matter.

Studies of superconductivity now under way at the Bureau include several different lines of investigation. For example, the transition of a conductor from the superconducting state to the normal state as a function of current density was determined. Other investigations during the year dealt with the differences beween the behavior of superconductors at microwave frequencies (10 billion cycles per second) and their behavior with direct currents. Whereas the resistance of a superconductor completely disappears with direct currents, some resistance is still observable at these high frequencies. The behavior of this high-frequency resistance as a function of temperature and with different metals is of great scientific interest. A third problem concerned the interaction between a magnetic field and the surface currents which it sets up in a superconductor. The retarding torques exerted on a superconducting sphere when it is rotated wtih respect to the applied field were measured. This experiment aids in determining the forces which act between the superconducting electrons and the lattice of the metal.

The anomalous properties of liquid helium II are being investigated below 1° K, principally through study of the phenomenon known as "second sound." Liquid helium, cooled to 2.19° K (the λ-point) or lower, acquires properties so unique that it is often described as a fourth state of matter. One of these properties is an abnormally high heat conductivity, for the basic nature of heat propagation undergoes a complete change at the λ-point to a form of wave motion (second sound) which travels with a definite velocity. This velocity is determined by introducing heat pulses into liquid helium and measuring the time they require to travel a known distance to a thermometer.

The determination of specific heats, heats of transition, entropy, and free energy of the elements and compounds in the temperature range 12° to 370° K has long been an active program at the Bureau. During the year, measurements were made of the specific heat of diphenyl ether from 13° to 360° K. An important aspect of the calorimetric program is the use of the calorimeter for the determination of purity. By measuring the triple-point temperature as a function of the fraction of sample melted in a heat-of-

fusion experiment, impurities as small as a few parts per million can be measured. Purities of a number of compounds were determined, including normal heptane, isopropyl alcohol, diphenyl ether, and methylcyclohexane. Normal heptane is now being prepared for use as a calorimetric standard.

A new program of calorimetry at temperatures between 1° and 20° K was begun. This program will involve determination of the specific heats of metals, semiconductors, and superconductors to provide basic information on the specific heats of conduction electrons, which are not otherwise obtainable. A calorimeter of a considerably higher potential accuracy than has been obtained before was designed and is now being constructed for this investigation.

Gas Turbines and Jet Engines

The advent of gas turbines and jet engines as practical power plants has given rise to urgent needs for research in new fields and the extension of old fields to higher temperatures, pressures, and velocities. During the year important contributions were made to the solution of problems concerned with combustion, control of the fuel supply, and the measurement of temperature, composition, and thermal properties of exhaust gases. While activities in these fields were carried on at the request of the military services, the results also possess great utility for peacetime applications of gas turbines.

Facilities for operating turbojet and ram-jet combustors were improved and expanded, permitting studies at 2,000° F of instruments in gas streams having velocities of 1,800 feet per second. Classified research was done on the evaluation of commercial combustors and their constituent parts and on the determination of factors basic to burner design. Since flame speed and temperature are of prime importance in burners of this type, apparatus was built for measuring these characteristics under those conditions of temperature and pressure which prevail in operating engines.

In the field of jet fuels, 24 pure hydrocarbons were synthesized, and the physical properties of each were accurately determined. Complementing previous work on 57 aviation gasolines, the heats of combustion of 32 samples of jet fuel produced under a tentative specification were determined by precise calorimetry. A single linear equation was developed by means of which the heat of combustion of each of the gasolines and each of the jet fuels can be calculated, within a few tenths of 1 percent, from the density and the aniline point. With this equation, the heats of combustion of other hydrocarbon fuels having similar properties can be computed from simple measurements without recourse to the difficult technique of calorimetry.

In addition to normal calibrations of experimental temperature-sensing instruments, measurements were made of heat loss by radiation, rate of response, the effects of gas velocity, and ability to withstand corrosion in streams of exhaust gas. A special thermocouple consisting essentially of short lengths of iridium and iridium-rhodium alloy wires with a cooled

support was developed, calibrated, and found to have considerable promise for applications in gases at temperatures up to 3,500° F.

In the metering of fuels, the sensitivity of flowmeters of the Rotameter type to the density and viscosity of the fluid was reduced markedly by proper attention to float design. A rapid and safe method was also developed for flow-testing spray nozzles and some of their constituent parts with air.

5. Atomic and Radiation Physics

Recent advances in atomic and molecular physics have made necessary new techniques, instruments, standards of measurement, safety provisions for workers and consumers, standard samples for calibration purposes, and methods of testing and evaluation in this rapidly expanding field. The Bureau is now engaged in a broad program of fundamental research and standardization dealing with atomic and molecular spectra, radiometry, physical electronics, electron optics, mass spectrometry, X-rays, radioactivity, and atomic and nuclear constants. A portion of the work specifically directed toward the atomic energy program is supported by the Atomic Energy Commission. Much of the remainder is in closely related lines of research and is carefully coordinated to avoid duplication of effort.

Magnetic Moment of the Proton

The gyromagnetic ratio of the proton was measured precisely in absolute units by the method of nuclear resonance absorption in a magnetic field. The new value,

$$\gamma = 2.6752 \pm 0.0002 \frac{\text{radians}}{\text{gauss sec}}$$

is considerably more accurate than any reported previously. All previous measurements approaching this precision have been made in terms of the relative values of other physical constants and not by direct measurements. Because of the importance of the gyromagnetic ratio as a fundamental nuclear constant, refinement in its measurement leads to a more precise knowledge of other important atomic constants. Two of these, the magnetic moment of the proton and the charge-to-mass ratio of the electron, are, as a result, now known with better precision.

The magnetic moment of the proton calculated from this measurement is 1.4102 ± 0.0005 dyne-cm/gauss. This value now has essentially the same accuracy as the Planck constant h, which must be used in the calculation, and represents the first precise determination of the proton moment in absolute units. The charge-to-mass ratio of the electron, e/m, evaluated in terms of measurements by others of electronic and nuclear g factors, is

$$e/m = 1.75878 \pm 0.00016 \times 10^7.$$

The determination of the gyromagnetic ratio differs by a small but significant amount from previous measurements by less direct atomic-beam

The Bureau will soon make radioactive standards of carbon 14 available in the form of glass ampoules containing 25 milliliters of a 0.1-molar solution of sodium carbonate (p. 22).

methods at Columbia University. Careful examination shows that the difference can be explained by the radiation correction to the electron moment predicted theoretically by Schwinger. The two measurements thus combine to give quantitative verification of an important contribution to the physics of the electron.

The nuclear resonance techniques developed in the course of this work can be applied to good advantage wherever the strength of a magnetic field must be closely regulated. The problem of magnetic field regulation arises widely in the use of scientific apparatus (cyclotrons, mass spectrographs, and beta-ray spectrometers) and in industrial equipment (servomechanisms and electromagnets).

The new measurement of the proton's gyromagnetic ratio also provides an accurate secondary standard for magnetic fields. In the past, laboratory measurements involving both magnetic and electric fields have been limited by the low accuracy of the magnetic measurements. Now the situation is reversed, and magnetic fields can be measured more accurately than electric fields. This advance will be especially useful in the design and development of scientific and industrial apparatus employing magnetic fields where it is important to know accurately the spatial distribution in the field.

Spectra of Fission Products

When uranium atoms of mass 235 are split, the fission products contain more than 30 atomic species, including two types of elements that have

never been found in nature. Milligram quantities of the two artificial elements, now known as technetium 43 and prometheum 61, have been separated from fission products by the Oak Ridge National Laboratory and loaned to the National Bureau of Standards for spectroscopic study requested by the Atomic Energy Commission. Spectroscopic data are experimental evidence from which the electronic structure and energy levels of the atom are determined. Thus, such data are important to all scientists investigating the properties of these elements or engaged in research in atomic and nuclear physics.

Authoritative descriptions of the optical spectra characterizing these new elements are being made by exciting them in two or more ways, photographing the spectra, measuring the wavelengths and relative intensities, and sorting out the lines due to neutral atoms from those belonging to ionized atoms. A preliminary description of the first two spectra of technetium is nearing completion; it adds more than 2,000 lines to the data of spectroscopy. The stronger lines of both spectra have been classified as transitions between identified energy levels which reveal the electron configurations of technetium atoms and ions in normal and excited states. In complexity and excitation, the spectra of prometheum resemble those of some other rare-earth elements; several thousand new spectral lines have been observed for this element, but their description has just begun.

Semiconductors

At present, one of the most active fields of research in physics is the study of the semiconductors. This field was greatly stimulated by the wartime development of crystal diodes, which were extensively used in radar work and are now finding numerous applications in electronic components. The recent discovery of a crystal triode, the transistor, which may be used as replacement for vacuum tubes in amplifiers, has also aroused interest in the subject.

A laboratory has been set up at the Bureau for the investigation of three specific topics relating to semiconductors. One is the determination of the properties of a semiconductor in the region where electrical conduction changes from electron type to hole type. It is believed that the results will clarify the phenomena occurring in the transistor.

Another study is concerned with the measurement of the Hall effect and conductivity. This information is essential for an evaluation of a semiconducting material. Apparatus is being assembled to study the properties of titanium dioxide, which has considerable promise for use in circuit elements involving semiconductors.

The third investigation is on lattice defects in ionic crystals and semiconductors. These defects have a great influence on conduction properties, and a knowledge of the number of such defects is essential to a complete understanding of the conduction process.

Cathode Emission Processes

The Bureau is making an investigation for the Office of Naval Research of the physics of composite cathodes. Very low-density vapors of atoms of selected chemical elements are projected upon the cathodes during pulses of a few millionths of a second. The effect of these pulsed vapors on the electron emission of the cathode is observed with a very high-speed cathode-ray oscilloscope. The manner in which the pulsed atomic material affects the electron emission can be learned from observation of the number of microseconds between the arrival of the vapors and the resulting effect on the emission. Results at present indicate that a very small quantity of material pulsed onto a cathode will cause significant emission changes.

Radioactivity

The increasing use of artificially produced radioactive isotopes and nuclear particles in medical treatment, scientific research, and industrial applications has created a need for standards of the commonly used isotopes and for more precise and reliable methods of measuring their radiations. For example, a program of cooperative measurements showed discrepancies of several hundred percent in the determinations by various laboratories of amounts of radioactive material in samples of substances used for medical treatment. After considerable investigation and development work at the Bureau during the past year, a method of calibrating and distributing standard samples of radioactive iodine and radioactive phosphorous was finally devised. As a result of this program, the variations in measurement of these two substances were reduced to a few percent.

A similar program for the establishment of a standard for radioactive carbon (C^{14}) was essentially completed, and calibrated samples of this isotope will soon be available for distribution. An important part of this investigation is the determination of the half-life of C^{14}, i. e., the time required for a given quantity of the isotope to decay to one-half its original amount. Results thus far obtained indicate a provisional value of 5,600 years.

Investigations preliminary to the establishment of standards of other radioactive isotopes are still in progress. In order to calibrate a radioactive standard, it is necessary to know the kinds of radiation emitted by the isotope, the energies involved, the rates of emission, and the complete disintegration scheme of the radioisotope and of all its decay products. Hence, considerable time and effort have been devoted during the past year to studies of beta and gamma emission and the determination of beta-gamma and gamma-gamma coincidence rates. An example is the determination of the beta- and gamma-ray spectra of iodine 131. From these data and from observations on the beta-gamma and gamma-gamma coincidences, the nature of the disintegration scheme for this isotope was established. Similar work has been performed for gold 198, showing that

it disintegrates by emission of a single beta ray followed by a single gamma ray. On the basis of this information, it will be possible to prepare calibrated standards of the isotope.

The method of beta-gamma coincidences for the determination of coincidence rates is generally difficult to apply to radioisotopes decaying by positron emission because of the disturbing effect of the annihilation radiation. A method involving the magnetic deflection of the positrons was developed which now permits the use of the coincidence method for measuring such radioisotopes as sodium 22, used extensively in medical work.

Protection Against Radiation

The present availability of large quantities of gamma-emitting radioactive materials from atomic piles and the development of commercial models of high-energy accelerators have made problems of radiation protection and shielding increasingly important. Exact wall thicknesses and optimum types of construction for protection from extremely high-energy radiations must be obtained. Radioactive materials are now or will soon be available which will produce the same radiation output, at similar photon energies, as the million-volt commercial X-ray machines, but at a considerably smaller cost. These radiations should thus find extensive applications. In order for their use to be economically feasible, however, it is necessary to know the minimum protection requirements. Experimental conditions for such determinations require large laboratory spaces to reduce scattering from nonessential sources and means for handling large masses of absorbers. Experiments of this type are now being carried on at the Bureau as part of a broad program on radiation protection.

At the request of the Atomic Energy Commission, the attenuation of the gamma rays from cobalt and radium in iron, concrete, and lead was obtained under broad-beam conditions which closely simulate those found in practice. Data were obtained for thicknesses up to 2 feet of concrete and up to 4 inches of iron. From these data an approximate method was worked out for computing required thicknesses of other barrier materials having an atomic number below that of iron. Plans are now under way to obtain similar information with the Bureau's new 50-million-volt betatron.

X-ray Equipment for Medical Use

During the last war, medical X-ray equipment available for use by the armed forces did not adequately meet their requirements. For example, unsatisfactory operation of the equipment with gasoline-electric generators was a source of much difficulty. In order to be prepared for any future emergency, the Department of the Army has now undertaken an extensive program to develop X-ray equipment specifically for field use. This program is under the technical supervision of the National Bureau of Standards. While the development work is being carried out mainly by X-ray

equipment manufacturers under contracts, facilities and trained technical personnel at the Bureau are being utilized for testing and study of the models as they are developed, to determine whether they will meet the military requirements under conditions simulating a wide range of environment and conditions of use. These studies also include an analysis of the operation of the equipment with gasoline-electric generators, recommendations for modification of generator design, and the development of accessory items to provide operational characteristics equivalent to use on the usual commercial power lines.

The development work is now about one-half completed, and the results appear to have considerable significance for the improvement of civilian X-ray apparatus. For example, the use of gas instead of the usual oil as the insulating medium in the full-wave generator reduces weight, greatly facilitates replacement of rectifier tubes and repair operations, and permits the unit to be shipped filled with the gas and ready to operate.

Mass Spectrometry

Many industries—e. g., gas, petroleum, synthetic rubber, chemicals, and plastics—depend upon the results of gas analyses for control in production processes. One of the newer analytical instruments, the mass spectrometer, is proving remarkably useful for the analysis both of gases and of volatile liquids. This instrument can, in one operation requiring only a few minutes, separate a very complex mixture of gases, and in many instances the separation provides an immediate identification of each compound in the mixture. The quantitative determination, however, is accomplished by mathematical analysis of the spectrometric data, and this may require hours or days depending on the complexity of the mixture and the method of computation. In order to eliminate much of this calculation and delay, the Bureau is cooperating in a program for the systematic compilation of the mass spectra of pure compounds. Spectra of more than 100 pure hydrocarbons were measured and analyzed during the past year for inclusion in the catalog of mass spectra issued by the American Petroleum Institute.

Further studies of the application of mass spectrometry to research on molecular structure and to chemical analysis were continued. Techniques for obtaining quantitative analyses of liquids of low vapor pressure were investigated. In connection with this work, a micromanometer was developed to measure pressures in the range 10 to 50 microns with a precision of 1 percent. The instrument is a diaphragm manometer in which displacement of the diaphragm is measured electrically.

An investigation of the thermal dissociation of six polymers used in common plastics was carried out. The volatile dissociation products were analyzed by the mass spectrometer, and microanalytical methods were developed to measure the average molecular weight of the nonvolatile products. The results give insight into the molecular structure of polymers and the mechanism of dissociation. In addition, the technique of mass-

spectrometer analysis of volatile dissociation products affords a method for the chemical analysis of polymers.

Properties of Magnetic-Type Electron Lenses

Since the optical properties of magnetic lenses used in electron microscopes and other electron-optical systems are determined by their axial field distributions, it is desirable to have some means of measuring these distributions with high accuracy. Apparatus was therefore constructed for evaluating such fields directly by measuring the force exerted on a specially wound probe. Although this coil-balance method is in general use for magnetic measurements, its application to lenses required special adaptation because of the small dimensions involved. Preliminary experiments with the device have indicated that the fringe fields of magnetic lenses contain certain irregularities which merit further study.

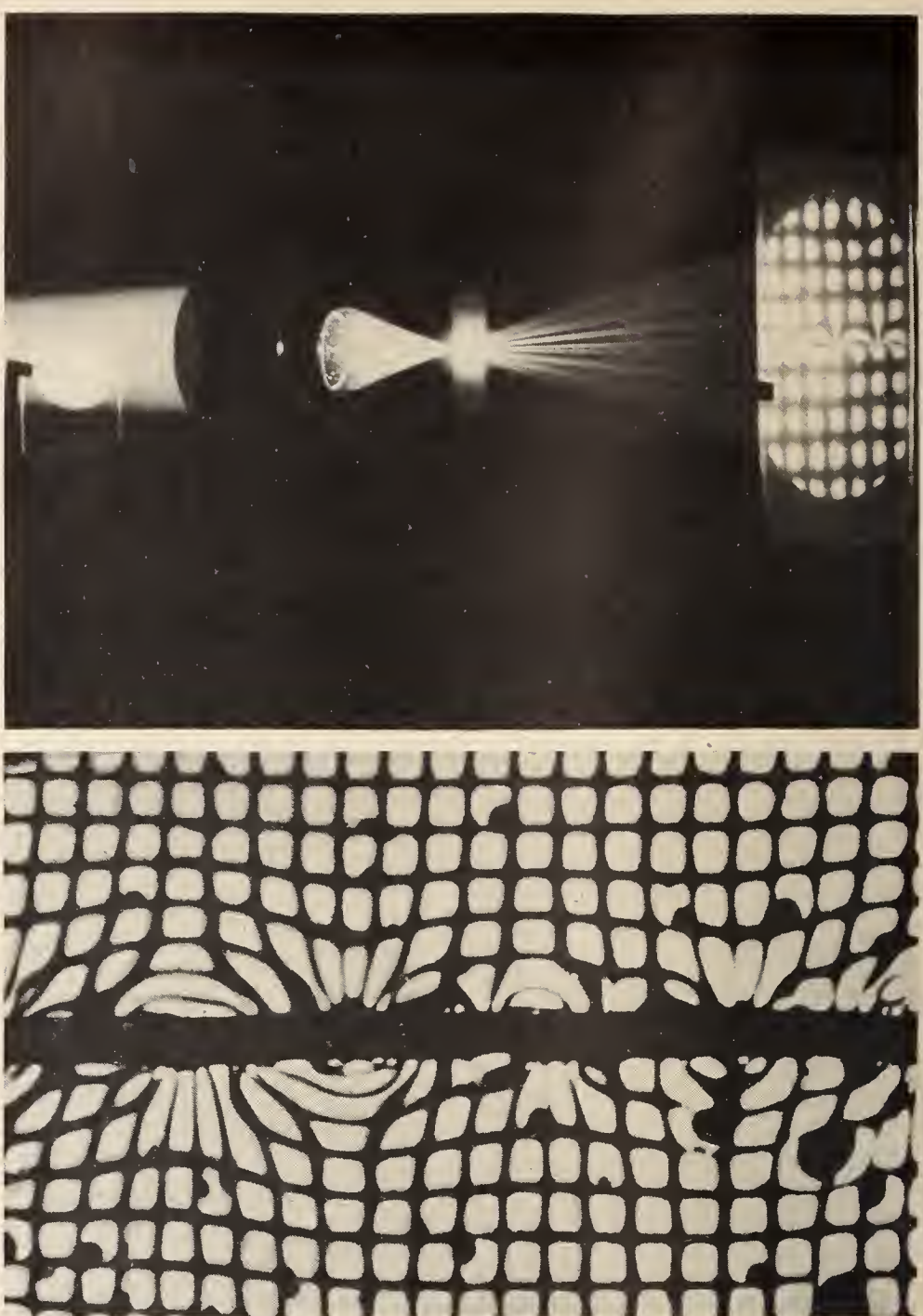
Electron-Optical Shadow Method

An electron-optical shadow technique was developed, providing a valuable tool for the quantitative study of electrostatic and magnetic fields of extremely small dimensions. The new method makes use of an electron lens system to produce a shadow image of a fine wire mesh placed in the path of the electron beam. From the distortion in the shadow network caused by deflection of the electrons as they pass through the field under study, accurate values of field strength are computed. Thus it is possible to investigate quantitatively fields that have not been susceptible to other methods of investigation, for example, the fringe fields from the small domains of spontaneous magnetization in ferromagnetic materials.

The new development should provide a powerful means for broadening present knowledge concerning space-charge fields, fields produced by contact potentials, patch fields in thermionic emission, charge distribution in a gaseous plasma, waveguide problems, and the basic magnetic properties of metals. Though similar in some respects to the electron-optical Schlieren method previously developed at the Bureau, the shadow method is much better adapted to precise determinations of field intensity.

Perhaps the greatest value of the electron-optical shadow method lies in its utility for exploring complex electric and magnetic fields of extremely small dimensions or in which a probe of size greater than the electron would disturb the field under study. In the past, calculations of the field intensity at a point have been limited to those special cases in which the geometry of the field exhibits a high degree of symmetry. The shadow technique now provides data for accurate calculation of the absolute value of the field intensity in selected planes about a specimen of any size or shape without altering or disturbing the field.

The method is thus well adapted to investigation of the fundamental nature of ferromagnetism. Experiments now under way at the Bureau in-



The electron-optical shadow method, a new technique developed at the Bureau, makes it possible to photograph and study quantitatively electrostatic and magnetic fields of extremely small dimensions. Above: the method is illustrated by an analogous experiment in light optics. Below: pattern produced by the field of a magnetic recording wire. These two photographs were together awarded first prize in the Third Annual Photography-in-Science Salon of the American Association for the Advancement of Science in September 1949.

clude a study of the behavior of the fringe fields of the ferromagnetic domains; in this work a single crystal of cobalt having very large magnetic domains is being used. An extension to ferroelectric materials is also contemplated for the purpose of checking the domain theory of these substances; of particular interest will be a study of the polarization of barium titanate and other high-dielectric materials which are now being widely used in the production of small-sized capacitors for radio, radar, and television.

In another application of the shadow method at the Bureau, space-charge fields in several types of apparatus employing electron beams are being investigated. In this connection, use of the method with a pulsed electron source for the stroboscopic study of fields that vary with time is under study.

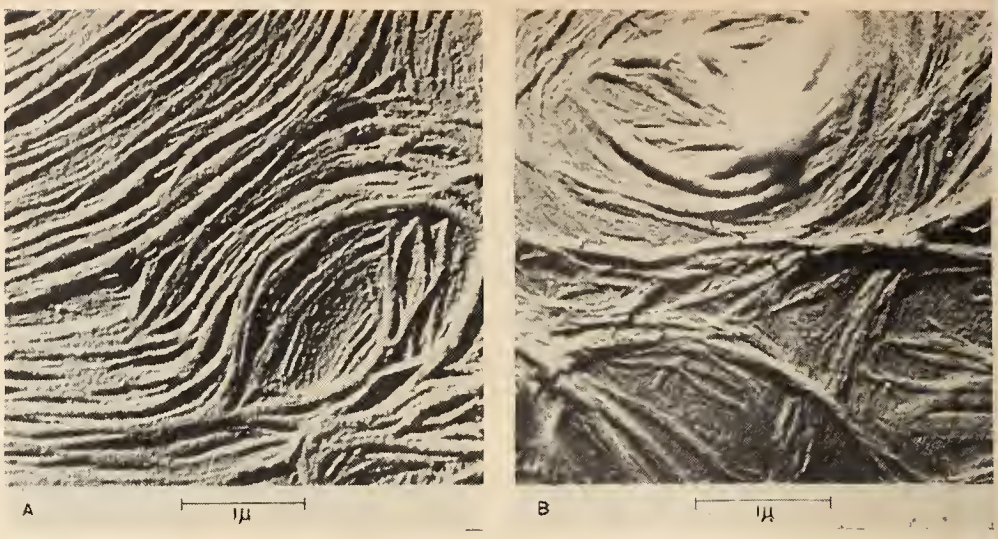
It has been suggested that the electron-optical shadow method may also be of value for the calculation of field intensities within a waveguide. Use of waveguides as conductors and circuit elements in ultra-high-frequency radar and communication often leads to arrangements whose geometry is too complicated for expression in any system of mathematical coordinates. Thus the electronics engineer, having in many cases only an intuitive picture of the field distribution at junctions and elbows of the guide, must rely on empirical methods in designing waveguide techniques and equipment. By the use of suitable auxiliary techniques, it is hoped that the shadow method may be adapted to the calculation of field intensities in regions of a guide that are not at present susceptible to analytical treatment.

6. Chemistry

A wide range of fundamental and applied research is carried on in physical, analytical, organic, and inorganic chemistry. Special laboratories are devoted to organic protective coatings, detergents and adsorbents, carbohydrates, metals and alloys, pure substances, electrodeposited coatings, gases, acid-base indicators and pH standards, and hydrocarbons. Highly varied techniques are used in the analytical work of the several groups; many types of physico-chemical measurements are made: an entire section, by way of illustration, is occupied with emission spectroscopy as an analytical tool. Most of the Bureau's "Standard Samples", critical in industrial quality control and in research work throughout the Nation, originate in this division.

Properties of Soaps

Although soaps and other kinds of cleaning materials have been in common use for centuries, there have been no universally accepted quantitative methods for determining their washing or cleansing power. In an effort to apply some of the newer scientific techniques to the problem, electron-microscope and X-ray diffraction studies of soap crystals were carried out at the Bureau, revealing characteristic features for each type of soap molecule that can be used for its identification. The electron microscope also indicates the individual soap forms that are present in a mixture, such as a



Electron micrographs of soaps and soap mixtures reveal morphological features that serve as excellent guides for a quick characterization of the pure alkali soaps themselves (A) and for the identification of the components of commercial soap mixtures (B) (p. 27).

commercial soap prepared from mixed fats or oils. This is not always possible with X-ray observations because of the nature of the diffraction patterns obtained. In conjunction with physico-chemical measurements of aqueous soap solutions, these data offer an explanation of the mechanical process of cleansing and, at the same time, suggest a basis for evaluating the cleansing power of the different types of soap.

Fundamental Chemistry of Sugars

The manifold role of ammonia and amino compounds in biological and other branches of organic chemistry makes important the study of the amino carbohydrate derivatives. The Bureau's development of methods for the preparation of 1-amino-uronic amides has provided a useful process for the separation of uronic acids. This work also offers a key to some fundamental problems of organic chemistry, including reactions that may be involved in life processes. It was found that the 1-amino-uronic amides, as well as the simpler glycosyl amines, are sensitive to hydrolysis in a limited range of acidity, pH 4 to 6. This striking sensitivity is explained by an equilibrium state involving (1) the glycosyl amine and its cation and (2) the corresponding imine and its cation. The system seems adequate to account for the sensitivity of certain enzymes in regions of restricted acidity and for the peculiar role which ammonia plays in some condensation reactions of aldehydes.

Infrared Spectrometry

In recent years infrared spectrometry has found extensive use as a tool for the analysis of mixtures of organic compounds and as a means of corre-

lating the properties of substances with the structure of their molecules. During the year a study of the infrared absorption of sugars and sugar derivatives was begun as a phase of the continuing work on the fundamental chemistry of carbohydrates. The spectra of 15 sugar derivatives dissolved in carbon tetrachloride were recorded to identify absorption bands characteristic of alpha and beta forms as well as those associated with the ring structures of glucose, mannose, galactose, etc. The spectra of nine substituted alcohols (3-pentanols) were also recorded to study the association of the hydroxyl groups and to verify the assignment of the band at 2.86 microns attributed to the dimer structure: this work provides information with which to interpret the structure of the sugars and to elucidate the structure and mechanism of moisture absorption of cellulose for correlation with physical properties.

Properties of Corn Products

Products derived from corn are the basis of a very large industry in the United States. Under the Research Associate plan, the Bureau is engaged, with the Corn Industries Research Foundation, in cooperative research on those properties of corn products that are fundamental to the industrial processing of the materials. Among these products dextrose (corn sugar) is of outstanding importance. During this year extensive systematic measurements were made of the vapor pressure, boiling points, and heat capacities of dextrose solutions.

Paints, Varnishes, and Lacquers

It is estimated that the Government spends $100,000,000 annually on paints and related materials. The cost of applying them is perhaps four times this figure. The knowledge of paints, varnishes, and lacquers which has been accumulated at the Bureau through many years of work on these materials is thus of steadily increasing value to Government agencies in problems of procurement and utilization. During the year special emphasis was placed on the development and improvement of specifications in this field to keep abreast of technological changes and the needs of the Government. Thus, in testing for conformance to specifications, priority was given to samples representing large Government purchases or centralized Government procurement plans. For the last 6 months of the fiscal year, 40 percent of the paints and 13 percent of the varnishes tested for conformance to Government specifications were found to be substandard. This clearly shows that Government procurement of these important commodities is as yet far from satisfactory and that more systematic attention should be given to its improvement.

Dissociation Constants of Organic Compounds

When certain organic compounds are dissolved in water, they dissociate to give acid or alkaline reactions that are important in many fields, includ-

ing biology and medicine. Several well-known methods are available for the determination of the physico-chemical equilibria if the dissociation proceeds in a simple manner. However, for systems in which two or more dissociations are involved, the procedures are more complicated, especially if the constants have nearly the same values.

Many organic substances which are colorless in solution have broad, intense absorption bands in the ultraviolet region of the spectrum. The bands may shift considerably in position and intensity if the acidity or alkalinity of the solution is changed. On the basis of this phenomenon, a method of calculating two closely overlapping dissociation constants of organic compounds from spectrophotometric data was developed. While extensive experimental observations and subsequent calculations are required to determine the amounts of the several dissociation products in solution, the method is especially useful for materials that do not dissolve readily and for solutions of low concentrations where other procedures give low precision or fail.

Hydrocarbons

The work on hydrocarbons, performed largely in cooperation with the American Petroleum Institute through its Research Projects 6 and 44, has continued to produce results of fundamental importance for the industrial and scientific laboratories of the petroleum, chemical, and rubber industries. During the year, a new theoretical analysis of the fractionating process of adsorption was completed; the number of individual hydrocarbons isolated from one representative crude petroleum was increased to 91; reports were completed on precision measurements of the simple physical properties of 60 highly purified hydrocarbons of the API-NBS series; purification and determination of purity were completed for 25 hydrocarbon compounds; determinations of the purity of 3 organic sulfur compounds were completed; and arrangements were made for commercial production of a full-scale laboratory model of the rotary concentric-tube distilling column previously developed at the Bureau.

The tables of selected values of physical and thermodynamic properties of hydrocarbons, which now contain 722 pages and cover 456 hydrocarbons and related compounds, are being used by nearly 1,500 laboratories in this country and abroad. The catalogs of spectral data, which are largely used by industry for analytical purposes, now include the following: Infrared spectra, 879 pages, 419 compounds; ultraviolet spectra, 293 pages, 181 compounds; Raman spectra, 159 pages, 155 compounds; mass spectra, 364 pages, 277 compounds. Approximately two-thirds of the compounds are hydrocarbons and one-third are other types of compounds.

Thermochemistry

Experimental determination was completed of the heats of formation of several important substances, including diborane, pentaborane, cyclo-

octatetraene, and the five isomeric dimethylcyclopentanes. Work is in progress on a number of alcohols and the C_4 hydrocarbons. A total of 568 pages of tables of *Selected Values of Chemical Thermodynamic Properties* have been issued to date in loose-leaf form. The distribution of these data covers 1,580 laboratories, of which 140 are abroad. These tables bring together all available data in a form readily accessible to the engineer, chemist, and physicist in scientific and industrial research. They provide accurate values of the thermodynamic properties needed to calculate the optimum conditions for chemical manufacturing processes.

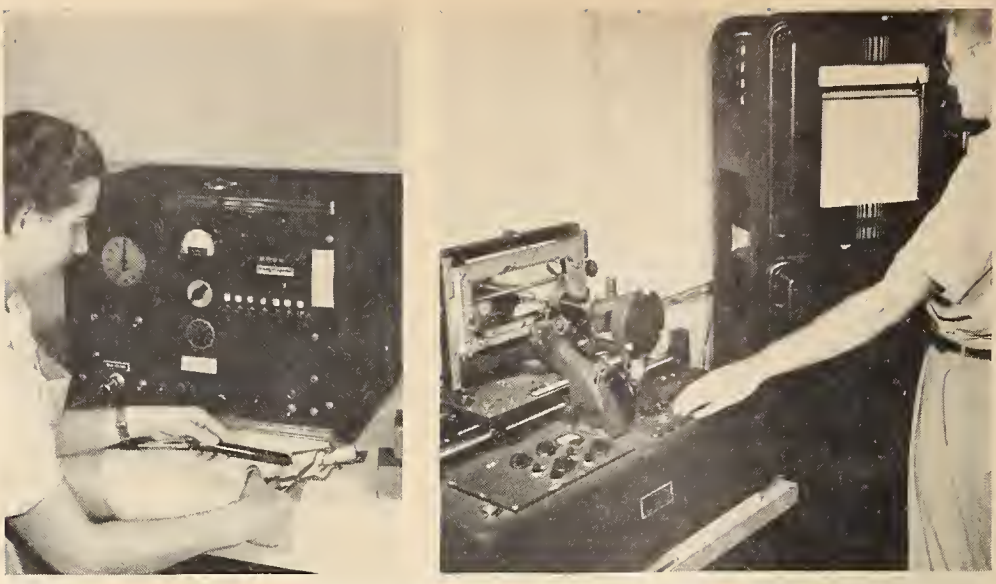
Gas-Burning Appliances

A large amount of work was done in an effort to develop expressions which will show the effects of changes in composition of fuel gases on the operation, and particularly on the safety, of gas-burning appliances. The subject is one of great importance when a change in the sources of gas supply to a community, or the supplementing of a supply during peak demands, is under consideration. Tentative formulas have been developed, but they require further study and comparison with the large amount of reported experimental data before they can be used with complete confidence. The elements of design which affect the performance of natural gas burners of the types commonly used in laboratories were studied experimentally. Most of the burners made commercially for the purpose have been tested. Conferences were held with the manufacturers which, it is believed, will result in considerable improvement in the burners offered for sale. A Federal specification for use in the purchase of burners was also prepared.

Electrodeposition

Research in electrodeposition was mainly concerned with the application of electroplating to military problems. However, several projects of general interest were completed or under way during the year. For example, the physical properties of nickel deposited under a wide variety of conditions were measured in cooperation with the American Electroplaters' Society. The results, now being assembled for publication, will facilitate the electroforming of nickel for specified purposes. Conditions were also determined for the codeposition of as much as 15 percent of phosphorus with nickel and cobalt. The deposits are relatively brittle, but they are hard and can be further hardened by heat treatment. This property may prove useful in special applications.

By use of the radioactive isotope, chromium 51, it was shown that in the chromic acid bath chromium is deposited directly from the sexavalent state and not, as often assumed, through the trivalent chromium that is also normally present. The results throw light on the mechanism of electrodeposition and also point the way to other researches with tracer elements. Investigations were begun on the deposition of metals such as tungsten,



Left: radioactive tracer techniques were used to study the mechanism of chromium plating. A Geiger counter is being placed inside a tube upon which radioactive chromium 51 has been deposited (p. 31). Right: the chemical composition of a sample material is determined in the Bureau's spectrochemistry laboratory.

molybdenum, titanium, and zirconium from aqueous solutions at temperatures up to 300° C and from fused electrolytes and nonaqueous solutions.

Redetermination of the Faraday

The present accepted value of the faraday was determined at the Bureau over 30 years ago. The method used was based on the electrolytic deposition of silver, an element whose atomic weight had been very accurately determined. In an electrochemical investigation now being conducted for redetermination of the faraday, emphasis is being placed on new methods of approach as well as on the checking of older methods. Anodic and cathodic reactions have been studied, and substances other than silver have been utilized. The values so far obtained do not differ greatly from the present one, but it is believed that the final result will have a higher order of accuracy. In the cathodic reactions very accurate methods of determining the ever-present inclusions must be developed. This work should also result in valuable information on electrochemical equivalents, chemical standards, and atomic weights.

Spectrochemical Analysis

In the last 25 years the development of spectrochemical analysis has greatly aided the analytical chemist in coping with the growing complexity of industrial materials, especially in the fields of metals and mineral products. Since the first crude beginnings in the twenties, the technique has increased steadily in accuracy and diversity of use.

During the past year emphasis was placed on the preparation of spectrographic standard samples and on improvements in methods of exciting

spectra and recording them. Five tin standards intended for the analysis of pure tin in industry were prepared by casting molten tin, with known additions of impurities, into bars which were then made into one-fourth-inch rods. Spectrographic tests showed that the rods were highly homogeneous with respect to the distribution of the 10 added constituents. The actual composition of these standards, which must be arrived at by conventional chemical analysis in addition to spectrochemical comparisons, is now being determined by a group of cooperating Government and industrial laboratories.

To improve speed and precision in testing spectrographic standard samples for uniformity, a direct-reading electronic spectrometer was installed and applied to the examination of two steel standards. The instrument provides an analysis of a sample for both major and minor constituents in 5 minutes. A high-voltage spark unit for the excitation of spectra was designed and built in order to provide higher precision in spectroscopic analysis, particularly of complex steels.

Pure Substances

Several special-purpose materials of exceptional purity were prepared. These include a substance intended to serve as a new thermometric standard and three calorimetric standards which will be issued to a group of laboratories cooperating in a program of refining and standardizing calorimetric procedures.

The calorimetric standards—normal heptane, benzoic acid, and synthetic sapphire—were prepared specifically for use in highly accurate measurements of heat capacity. The proposed new thermometric standard is diphenyl oxide. Cells containing this substance, whose freezing point is near 27° C, have been found to maintain a temperature constant to a few ten-thousandths of a degree for as long as 48 hours. Such cells can provide a means of calibrating platinum resistance thermometers at a temperature close to 25° C and thus keep them under accurate control in the temperature range where many measurements of physical and chemical properties are made. Measurements which will determine the exact degree of constancy and reproducibility of the diphenyl oxide cells are still in progress. An alcohol which freezes near 25° C will also be studied to determine whether its characteristics are in any way better than those of diphenyl oxide. When facilities permit, it is planned to issue to the public cells containing one or the other of these substances. They will supplement the benzoic acid thermometric standard which is now in regular production.

Mercury is a metal of diversified scientific uses, all of which demand a high degree of purity. For many years the Bureau has purified mercury for the use of its own laboratories and of several other Government agencies. This year the amount of metal purified was nearly 2,300 pounds, of which 700 pounds was required by one agency. By means of radioactive tracer

techniques, a study was made of the rate and degree of removal of base-metal impurities from mercury by treatment with nitric acid. The results showed that this much-used method of purification, if properly performed, can be regarded as "complete" with respect to all metal impurities other than gold, silver, and the metals of the platinum group.

Work was also done on the preparation of pure germanium, a metal whose characteristics as a transistor (semiconductor) are very sensitive to minute amounts of impurities. When sufficiently pure germanium is obtained, it will be possible to study the effect of adding various elements normally present as impurities as well as other elements which may be significant.

7. Mechanics

The mechanics of solids, liquids, and gases are the broad topics of research in this field. In scope the work varies from long-range investigations of basic mechanical phenomena to short-range studies of the mechanical action of practical apparatus.

Projects dealing with solids include studies of the propagation of sound over a wide frequency range through vibration-isolating materials such as rubber and felt; the absorption and transmission of sound in building materials; the piezoelectric coefficients of crystalline materials; the nature of elastic and plastic yielding in structural elements such as strips and plates under axial and under twisting loads; the strength under pulsating loads of riveted joints such as are used in aircraft; surveys of strain distribution under load in complicated engineering structures, such as fabricated columns, box beams, and bulkhead intersections, to check the "stress analysis" for the design of these structures; the measurement and computation of the vibration on model airplanes resulting from the landing impact; and improved techniques for measuring strain, displacement, acceleration, and force.

Work on the mechanics of liquids includes investigations of the propagation of surface waves and of waves at the interface between liquids of different densities, such as are present in the estuaries of rivers; the flow of water and air in plumbing systems; and improved techniques and standards for the precise measurement and control of pressure over a wide range.

Research on the mechanics of gases is concerned with the nature of the air flow at the surface of an airfoil; damping screens for smoother air flow in wind tunnels; the transmission of ultrasonic sound waves through gases at very low densities; measurement of turbulence at supersonic speeds; development of an "artificial ear" consisting of an acoustic coupler which will approximate the human ear in its ability to receive sound energy from a hearing aid; the recording and reproduction of audible sound, largely for application to the manufacture of talking books for use by the blind; the application of critical flow phenomena to the design of instruments and pressure lines; and accurate regulation of the flow and mixture of gases,

partieularly for maintaining an adequate supply of oxygen to the pilot during high-altitude flight.

Pfund Sky Compass

In polar regions the magnetic compass loses its value as a direetion indieator because of the weakness and directional variability in the horizontal component of the earth's magnetic field. In addition, a primary handicap to navigation has been the laek of a direction reference during long twilight periods when neither the sun nor the stars can be used. Considerable modification of conventional methods of aircraft navigation has therefore been required in such regions, where magnetic compasses and other existing instruments are inoperative. To meet this need, the National Bureau of Standards, at the request of the Bureau of Aeronautics, Department of the Navy, has developed a sky compass which indicates the direction of flight of an aircraft and can be used in determining its position.

The sky compass is based on the investigations made by the late A. H. Pfund of Johns Hopkins University and is an outgrowth of his twilight sextant. It operates on the principle that scattered sky light, particularly at twilight, is partially polarized in the plane containing the incident ray from the sun. The sky compass determines the plane of polarization and hence the direction of the sun. By use of a clock to rotate the sensitive element of the compass, the instrument is made to indicate continuously the direction of flight.

Talking Books for the Blind

Talking books are voice recordings of selected literature which, together with the reproducers for playing them, are supplied to the blind by the Library of Congress. As the Library has invested several million dollars in talking books, it recently requested the Bureau to investigatc talking book production techniques in current use and to set up specifications for the purchase of talking books and reproducers. The work was begun with the preparation of an interim specification for talking-book phonographs. Sample reproducers were tested for compliance with these specifications. The tests showed large variations among manufacturers in such quantities as tip radius of the playback needle, tone arm force, and loudspeaker response. In view of the apparent need for standardization in the industry, arrangements have been made with two of the largest suppliers of talking-book records for a cooperative study of their recording techniques, with the ultimate object of developing a standard technique. A concurrent investigation aims at determination of playback needle dimensions for maximum fidelity of reproduction. In connection with this work, 17 talking-book phonographs were tested for the Library of Congress. The test results were used as a basis for purchase of about 8,000 reproducers, costing approximately $250,000.

Left: the Pfund Sky Compass developed by the Bureau for use in polar regions where the magnetic compass is ineffective for navigation (p. 35). Right: a hot-wire anemometer for measurement of air speed is adjusted in the test section of the Bureau's 4½-foot wind tunnel (p. 37).

Electric Twinning of Quartz

The electric twinning which sometimes occurs in natural quartz renders it useless for radio and electronic applications. Moreover, detection of twinning is difficult, requiring first the sawing and then acid-etching of the quartz. A method of removing electric twinning systematically from raw quartz would thus be highly desirable. Such a method would make it possible for the reclaimed quartz to be used for radio-frequency oscillators and filters and would have considerable economic value. In order to throw some light on the twinning phenomenon, the piezoelectric properties of quartz were measured at high temperatures (near the inversion temperature of quartz). The results of the measurements show that one of the piezoelectric constants goes to zero suddenly at the inversion temperature. The two twinned forms of quartz which are produced on cooling through inversion will therefore have different energies when loaded mechanically in the presence of an electric field. This suggests the possibility of eliminating twinning by suitably combined electrical and mechanical loads. Experiments are planned to investigate this possibility.

Sound Transmission Through Walls

The amount of sound transmitted through a homogeneous building wall is much greater than the amount computed on the assumption that only the mass of the wall is effective in reducing sound intensity. A recently developed theory takes into account not only the mass of the wall but also its bending stiffness and internal dissipation of energy. A comprehensive laboratory investigation of both single walls and double walls (i. e., two single walls separated by an airspace) has shown this flexural theory to be

capable of predicting the transmission of airborne sound more accurately than the older theory. However, much theoretical and experimental work still remains to be done on the transmission through building structures of sound produced by impacts on floors and walls.

Boundary Layer Investigations

In cooperation with the National Advisory Committee for Aeronautics, the Bureau is conducting a long-range investigation of air flow next to the surface of a body about which air is moving or which is itself moving through the air. The flow near the surface in a thin region known as the boundary layer has been of vital concern to the aeronautical engineer almost since the dawn of flight: the phenomena taking place in this layer determine such factors as the drag of aircraft and the maximum lift of a wing. Certain of these phenomena, embraced by the term "turbulence," are so complex that definite progress has only recently been made in understanding them. Much of this progress is due to the use now being made of the highly versatile hot-wire anemometer to measure the statistical properties of turbulent motions. In research conducted in the Bureau's wind tunnels, measurements have been made of the energy of turbulence, the average dimensions of the air masses, and the shearing stresses produced by the turbulent motions. The primary objective of these studies was to reveal the cause of flow separation, which causes the stalling of wings and the high drag of blunt bodies. While this work contributed new information, it became more and more apparent as new theories were formulated that the real need was for a clear physical picture of the processes by which turbulent motions originate and are sustained against the damping action of viscosity. The complexity of the problem called for as much simplification as possible. These phenomena are therefore now being investigated along a smooth flat surface placed in a wind tunnel so that the air flows parallel to the surface. Measurements are being made of the proportions of the turbulent energy in different wavelengths in order to obtain data on the energy spectrum, which plays a prominent role in modern theories of turbulence.

Vacuum-Tube Accelerometer

Of basic importance for estimating the inertia forces in structures subject to impact and vibration are measurements of acceleration as a function of time. For this purpose a vacuum-tube accelerometer particularly suitable for use in aircraft and biomechanical research has been developed at the Bureau. The accelerometer, which has the appearance of an ordinary radio vacuum tube, has been used extensively by the Bureau in tests of model aircraft structures and by the Air Force to determine human tolerances in ejection seat research. It is being manufactured by one of the makers of radio vacuum tubes and is now commercially available.

The advantages of this accelerometer lie in its high natural frequency and large electrical output—adequate in many cases for use with relatively simple equipment. The acceleration-sensitive masses are two plates, which are spring-mounted so that one plate moves toward, and the other plate away from, a central fixed cathode when the tube is subjected to acceleration. The change in resistance of the electron stream between the plates and the cathode is proportional to the acceleration and may be recorded at a remote point.

Capacities of Plumbing Stacks and Drains

The question of how heavily a vertical soil stack of a given diameter can be loaded with drainage from plumbing fixtures in a building is a very controversial one on which little experimental data are available. Plumbing codes differ widely in the number of fixtures that they permit to be discharged into a stack of given diameter and in the way in which these fixtures may be distributed between different floors. A fundamental investigation of this problem, sponsored by the Housing and Home Finance Agency, is in progress. Studies have been made of the pressure and flow conditions that exist at the junction of horizontal drains with the stack when there is flow coming down the stack from the discharge of fixtures at higher levels. These data, together with a theoretical analysis of the conditions at the junction, make it possible to predict what back-pressure will be exerted on the flow out of the horizontal drain when a given flow is coming down the stack and a given flow going out of the drain. In this way the practical capacity of the drain can be predicted for any assumed conditions.

Flow of Stratified Liquids

Sponsored by the Office of the Chief of Engineers, Department of the Army, a comprehensive program of theoretical and experimental research on the flow of stratified liquids, such as a body of salt water under fresh water, has been undertaken. An important objective of this work is to develop model laws pertaining to models of rivers, harbors, and canals, where density currents of this nature are involved. The problem is of considerable economic importance, since it involves contamination of public water supplies, as in New Orleans, and of farm lands by intrusion of salt water from estuaries in the Sacramento River and possibly from navigation canals. Studies of the flow of a heavy salt or sugar solution from a model lock under the lighter fresh water in a channel have been made in two geometrically similar flumes, and further tests will be made in a larger flume now under construction. An investigation of the damping of solitary waves at the interface of two liquids of different densities has also been completed.

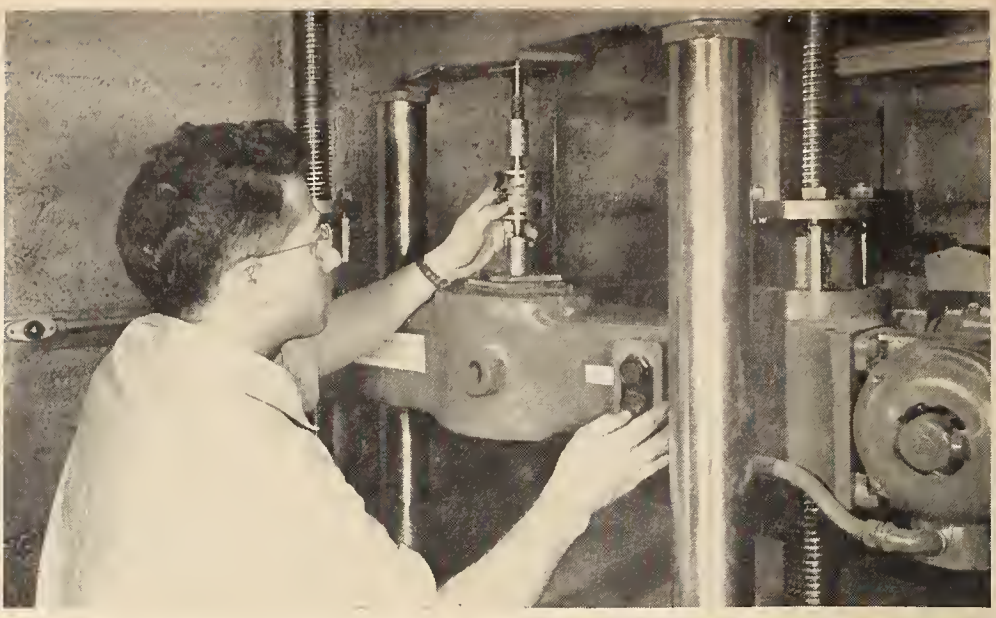
Investigation of Water Waves

A knowledge of the model laws for the formation of surface waves is important in the interpretation of tests of hydraulic models of harbors designed to determine the effect of surface waves on structures in the harbor. Experimental studies are under way to investigate the initial fetch required for wave development, the growth of wave length and height with distance, and the mechanism of energy transfer from wind to waves. For this purpose a flume 70 feet long is being used. It has a closed cross section and blowers mounted at both ends to create an artificial wind over the water. A theoretical study of tidal waves and a theoretical and experimental study of the absorption and reflection of waves by porous barriers are being made.

8. Organic and Fibrous Materials

The Bureau investigates rubber, plastics, textiles, leathers, and papers—organic materials whose characteristic properties are due to the long, chain-like structure of their molecules. Such compounds are formed in nature by a process known as polymerization, in which as many as several million individual molecules may be joined by chemical reaction. The complex molecular structure of high polymers, combined with their refusal in many cases to follow the laws of classical physics, has made it very difficult in the past to obtain definite fundamental knowledge of their properties. In recent years, however, rapid progress has been made in the theoretical science of high polymers, and new techniques have been developed for measuring their properties and studying their reactions. Many of the new techniques—such as X-ray diffraction, infrared spectroscopy, and electron miscroscopy—are being utilized by the Bureau to obtain a better understanding of the fundamental properties of high polymers, both natural and synthetic, and are leading to more adequate methods and equipment for developing and evaluating commercial products composed of these materials. During the past year, for example, information obtained in studies of the shape and size of molecules was utilized to incorporate rubber into sole leather in such a way as to improve wearing qualities.

New and continuing projects were under way in many branches of high-polymer chemistry and physics and of materials control and testing. In the field of rubber they included tire and tube evaluation, studies of second-order transitions and viscoelastic behavior, and analytical procedures for synthetic and natural elastomers. In textiles they embraced standardization of fading tests, infrared spectra and gas absorption of cellulose fibers, and abrasion resistance of fabrics. Investigations in paper technology were concerned chiefly with the photochemistry of cellulose, vapor barriers for buildings, papermaking materials and processes, and paper testing methods. In the work on leather, attention was directed to improvement of hides by impregnation with resins or rubber and by treatment with fungicides, the relation of chemical structure to physical properties, and tannage of fur-



In an investigation of the adhesive properties of a wide variety of adhesives and adherends (p. 40), tensile-adhesion strengths of the adhesive-adherend combinations were determined using dumbbell-shaped specimens and self-alining grips. Here a metal-tensile adhesion specimen is being positioned in a hydraulic testing machine.

skins. Projects in plastics included plasticizer-polymer relations, nature of adhesion, glazing materials, strength properties at high and low temperatures, and aging problems.

Among the investigations completed during the year were those relating to strain testing of rubber, deterioration of cotton fabrics exposed to the weather, laboratory and service tests of hand luggage, fire-retardant coatings for fabric-covered aircraft, thermal decomposition of polymers, and a statistical method for the study and control of test procedures.

Nature of Adhesion

The use of adhesives as a major aid to construction began during World War II in connection with intensive building programs for aircraft, ships, temporary housing, and containers. Emphasis in this new development was placed on synthetic resins rather than the conventional adhesive materials, such as animal glue, casein, starch, cellulose compounds, and rubber, which are used in packaging, bookbinding, and other industries. In 1947 approximately 100 million pounds of synthetic resins were used in adhesives, representing about 8 percent of the total resin production.

Fundamental investigations of adhesives and adhesion were conducted at the National Bureau of Standards in cooperation with the National Advisory Committee for Aeronautics and the Office of Naval Research. Experiments have shown that the strength of an adhesive joint is dependent not only on the attracting force between the adhesive and the adherend, but also on mechanical factors such as differences in the modulus of elasticity and

thermal expansion of the adhesive and adherend. Further studies are under way to obtain a better understanding of the effects of specific attractive forces on bond strengths.

Fire-Retardant Coatings for Aircraft

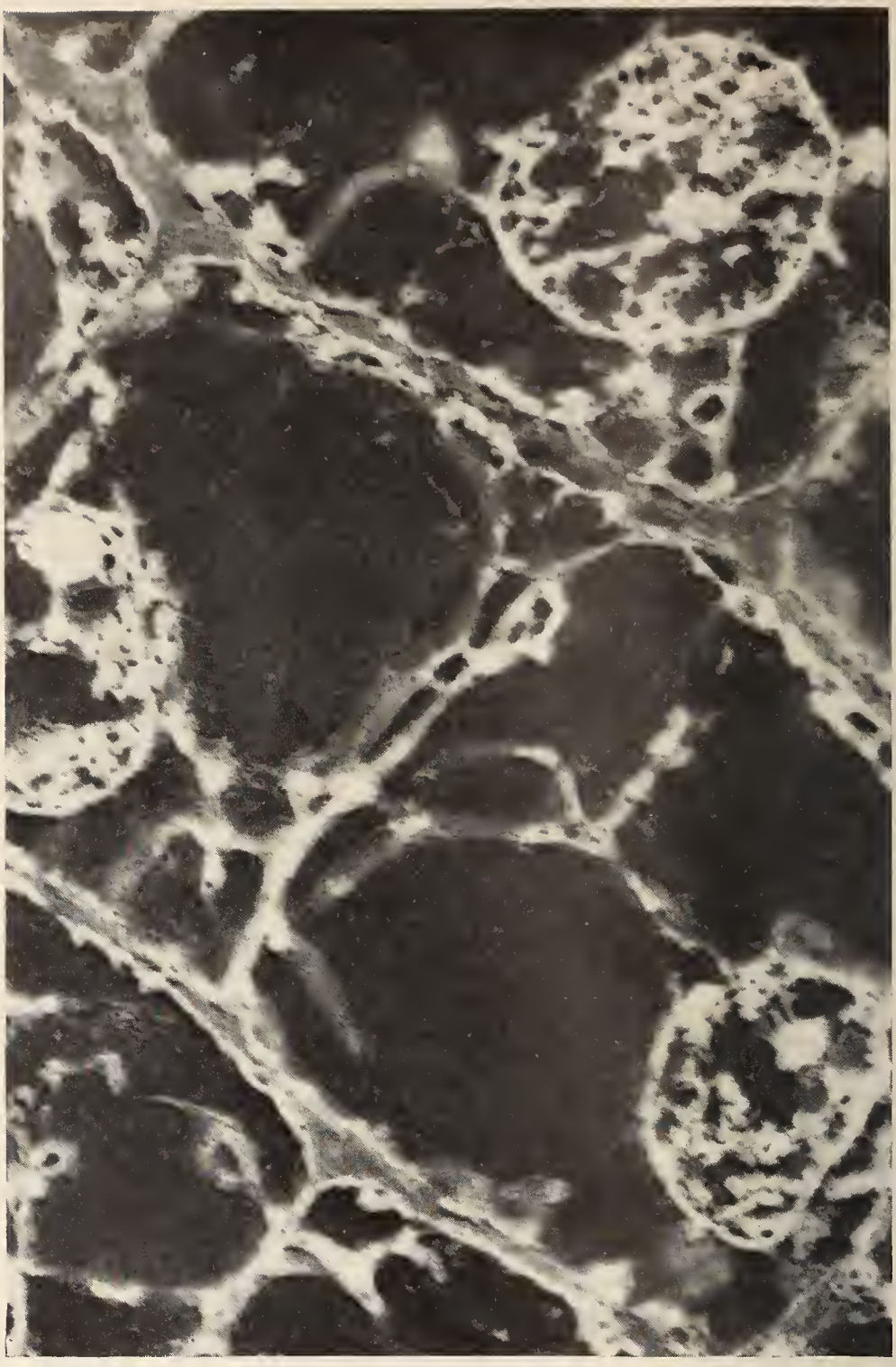
The highly flammable cellulose-nitrate dope used on airplane fabrics has been responsible for much loss of life and property by fire. Although dopes based on cellulose acetate butyrate are much more difficult to ignite and have a much lower flame velocity, even they are unsatisfactory in a power plant fire, in which flame from burning gasoline or oil may be in continuous contact with doped fabric for several seconds.

As the result of a joint research program undertaken by the National Bureau of Standards and the Civil Aeronautics Administration, coatings were developed for fabric-covered aircraft which approximately double the time interval between ignition of the fabric and its destruction by fire. These findings, based on both laboratory and wind-tunnel burning tests, provide a basis for more effective extinguishment of fires in flight, particularly those arising from power plants in small craft. The fire-retardant coatings which proved to be most successful include film-forming substances and pigments which in burning give off large quantities of noncombustible gases; substances which exclude oxygen by forming an impenetrable protective glaze; and compounds which absorb the heat of the flame through endothermic changes.

NBS Method for Microsectioning

The application of the electron microscope to many problems has been seriously hampered by the lack of a rapid, practical method for cutting extremely thin sections of organic materials. Because of the very slight penetrating power of the electron beam and the great relative depth of field involved, specimen structure is difficult to interpret when sections are over a fraction of a micron in thickness. Yet the techniques that have been available for preparing thin sections are quite elaborate and difficult, requiring expensive equipment and producing few usable sections. The Bureau therefore undertook to develop a rapid, efficient sectioning procedure which could be carried out in routine fashion by an operator without a great deal of special training. The resulting method, which goes far in accomplishing this objective, should be of decided advantage for the production of ultra-thin sections of tissues in such fields as cancer and virus research. The technique is now being applied at the Bureau to the microsectioning of rayon and other fibrous materials as part of a broad program in the fundamental study of high polymers.

In the new procedure, *n*-butyl methacrylate is polymerized around the specimen to produce an optically clear embedding medium having highly desirable cutting properties. A smooth, continuous advance of the speci-



Electron micrograph of an extremely thin cross section of onion root tip, showing cell walls and nuclei. The specimen was prepared for study using a new method recently developed at the Bureau for cutting very thin sections of tissue. This photograph was awarded third prize in the Third Annual International Photography-in-Science Salon of the American Association for the Advancement of Science in September 1949. (Total magnification $\times 3750$.)

men toward the knife of a slightly modified conventional microtome is then obtained from the thermal expansion of a metal specimen holder. Thus sections having integrity of structure and uniform thickness over a relatively large area may be cut one at a time. Metallic shadow casting is employed for enhancing contrast, increasing observable detail, and creating a three-dimensional aspect in some of the structures.

Shrinkage of Collagen

The shrinkage of collagen was studied in an effort to learn more about the fundamental nature of the reactions occurring in the tanning of leather. Isothermal measurements of the shrinkage of tendon collagen were made at various temperatures. The results show that shrinkage is a rate process and not a phenomenon occurring at a fixed temperature. The theory of absolute reaction rates has been applied to the data to obtain values of heat, entropy, and free energy of activation. Results so obtained are in good agreement with corresponding data reported on denaturation of soluble proteins. Studies on collagen subjected to tannage show that tannages may be divided roughly into two classes: (1) cross-linking, with increased heat of activation, and (2) non-cross-linking, with increased entropy of activation. Chromium compounds, the outstanding class of tanning agents, are found to produce cross-linking, which is presumed to occur between layers of polypeptide chains. Most tanning agents, on the other hand, are found to produce no cross-linking.

Impregnation of Sole Leather With Rubber

A process for incorporating rubber into sole leather was developed which improves the soles and at the same time conserves leather and tanning materials. This process consists of treating vegetable-tanned crust leather (the unfinished leather from which sole leather is made) with a solution of highly milled natural rubber in toluene and evaporating the solvent. The leather is then ready for use without the additional finishing processes that would otherwise be required. Laboratory tests indicate that the treatment improves the wear by as much as 50 percent and greatly increases resistance to water. The improved wear resistance, in turn, makes it possible to use portions of the hide that are not normally suitable for soles. Arrangements are being made for the pilot plant production of a number of soles for a service test on Army shoes.

Aging of Plastics and Rubbers

The life of plastics and rubbers in service depend upon complex processes of chemical degradation, depolymerization, and polymerization. To aid in predicting and improving their aging qualities, thin films of nylon, synthetic rubber, and other synthetic plastics and rubbers were exposed to heat, ultraviolet radiation, and various atmospheric conditions. The effects of catalysts, inhibitors, and other ingredients on the rate and course of the

degradation were also investigated. The volatile products were collected in some cases and analyzed by means of the mass spectrometer. The untreated and the treated specimens were examined by the following techniques to obtain information regarding the changes in the structure of the polymer: infrared absorption, ultraviolet absorption, measurement of viscosity of solutions, measurement of dielectric constant and dissipation factor, photomicrography, X-ray diffraction, electron microscopy, electron diffraction, and treatment with organic liquids. Some of the techniques gave definite indication of the course and mechanism of break-down.

Refractive Index of Natural Rubber

The well-known method of determining refractive index by the use of a prism and spectrometer was applied for the first time to measurements on rubber. A paper presented at the International Rubber Technology Conference in London describes the production of transparent rubber prisms and gives the results of measurements at five different wavelengths. The values of the index and the change of index with wavelength are found to be essentially the same as those of hydrocarbons of similar structure but of much lower molecular weight. It is possible to calculate the thermal expansivity from the refractive index and its rate of change with temperature.

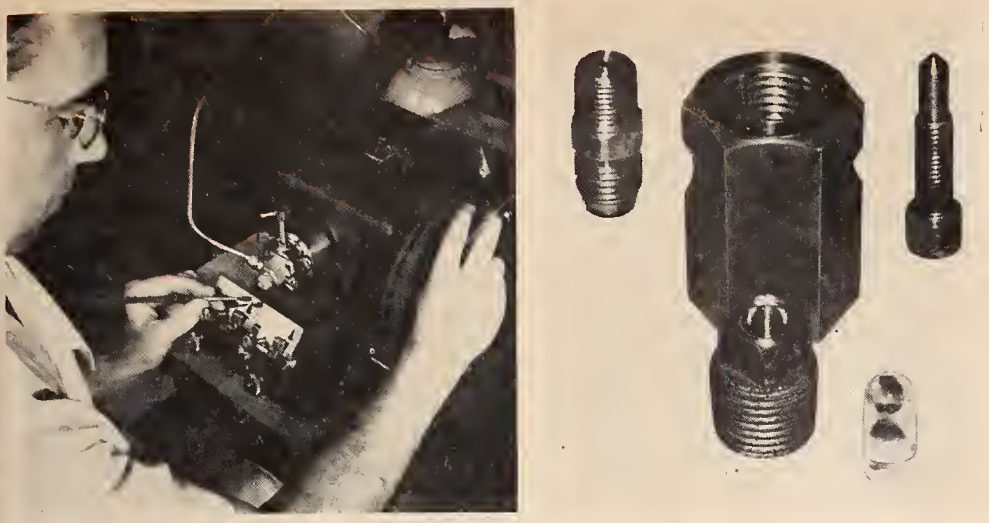
Photochemistry of Cellulose

An investigation of the effect of light on paper is being conducted as one phase of a continuing study of the preservation of records. The action of the light has been found to depend on its wavelength and the atmosphere in which irradiation takes place. Paper irradiated with far ultraviolet (wavelength about 254 millimicrons) is degraded much more in a dry atmosphere than in the presence of water vapor. Under these conditions oxygen apparently has no effect. However, upon irradiation with near ultraviolet (wavelength of maximum intensity at about 388 millimicrons), the changes that occur appear to depend principally on the presence of oxygen, and to a lesser extent on water vapor and the type of fiber from which the paper was made.

In the study of the photochemistry of cellulose, the degree of polymerization and aldehyde content are two important quantities to be measured. A very simple procedure was worked out for determination of the fluidity of cellulose dispersions in cuprammonium hydroxide, from which the degree of polymerization is readily obtained. An extremely sensitive method for determination of the aldehyde content of cellulose is now being studied, using sodium chlorite in a slightly acid medium as an oxidizing agent.

Infrared Analysis of Cellulose

An infrared spectrometric method for the quantitative estimation of the carboxyl content of cellulosic materials was developed. The method involves the application of Beer's law to absorption spectra of suspensions of



Very thin sections of tissue having uniform thickness, large area, and undistorted structure are prepared for electron-microscope study in almost routine fashion by means of a new technique developed at the Bureau (p. 41). Smooth, continuous advance of the embedded specimen toward the knife of a Spencer rotary microtome is provided by thermal expansion of a brass specimen holder (detail at right), which is clamped in the microtome a short distance in front of the knife blade.

cellulose in mineral oil and the location of the absorption band due to the carbonyl of the carboxyl. A carboxyl content of less than 0.02 equivalent per anhydroglucose unit can be detected by this procedure. Moreover, the sample required is smaller than that used in the chemical methods commonly employed for the determination of carboxyl in cellulose. With suitable modification, the new method is expected to be applicable to the quantitative estimation of certain other groups in cellulose and cellulose derivatives. It should thus contribute to an improved understanding and utilization of such important products as cotton, linen, rayon, films, certain plastics, and paper.

9. Metallurgy

Research and development in physical metallurgy are concerned with the preparation of metals and their alloys; the conversion of crude metal to useful shapes by forging, rolling, swaging, wire drawing, specialized casting processes, and powder metallurgy techniques; determination of the properties of metals and the effect of composition, heat treatment, and other variables on their behavior at high, low, and ordinary temperatures; study of the effects of applied stress, corrosion, and other factors on the useful life of metals and of means of combating these effects.

Projects completed or in progress during the year include a study of the occurrence and importance of iron as an impurity in magnesium-zirconium alloys; the use of polarized light to reveal the stages of deformation of Monel metal; investigation of the action of boron in promoting the hardenability of steel; laboratory studies of the chemistry of soil corrosion; field tests of pipe corrosion; marine-atmosphere exposure tests of aluminum and

magnesium alloys used in aircraft; studies of the effect of particle size and shape, compacting pressures, and sintering temperatures on the properties of metal parts produced by the methods of powder metallurgy; investigation of the effect of certain variables on the determination of particle-size distribution of the subsieve fractions of metal powders; preparation of "pure iron"; melting and casting of copper-tin alloys in a high vacuum; investigation of the causes of failure of metals in service; a study of the effects of strain rate and temperature on the creep characteristics of cold-drawn ingot iron; and development of a gage for measuring the reduction in area of test specimens during tensile tests at low temperatures.

Corrosion

It has been estimated that the United States has 500,000 miles of pipe lines, valued at approximately $6,000,000,000, for the transportation of water, gas, oil, and gasoline and that the annual cost of pipe replacement, primarily because of corrosion, is about $200,000,000. In an effort to reduce this yearly loss, the Bureau began in 1922 a program for the study of the underground corrosion of metals. This program has received the active cooperation of producers and users of pipe materials and operators of pipe lines. During the past year, the Bureau's field tests of pipe corrosion in varied locations throughout the United States were continued, and reports are now being assembled giving the results of 14 years of exposure of pipe sections made of iron, steel, copper and copper alloys, lead, and zinc. It has been found that steels with relatively high contents of chromium and nickel are highly resistant to corrosion in many soils. On the other hand, small additions of copper, nickel, or chromium, although effective in resisting atmospheric exposure, seem to have little, if any, effect on the resistance of steel to exposure underground. Dezincification of brasses apparently can be prevented in soils, as in certain other corrosive media, by the addition of very small amounts of arsenic.

Because of the time required to obtain data on corrosion and cathodic protection in field tests, efforts are being made to develop laboratory test procedures and equipment which will provide reliable information on the progress of corrosion in a relatively short time. Measurements of the potential of pipe specimens with respect to the surrounding soil environment, with and without cathodic protection of the specimens, are being made for correlation with the results of field tests of long duration.

Study of the corrosive effect of a marine atmosphere on aluminum and magnesium alloy sheet for aircraft use has been in progress since 1925 under the sponsorship of the Bureau of Aeronautics (Department of the Navy), the National Advisory Committee for Aeronautics, and the Department of the Air Force. During the year, exposure of 303 panels was completed and exposure of 157 new panels begun, including samples of a new construction material composed of a honeycomb core of aluminum foil, impregnated paper, and cotton fabric, all coated with aluminum.

Other current corrosion studies include determination of the relative merits of aluminum alloys, aluminized steel, Monel metal, galvanized steel, and zinc alloy sheets for use on housing exteriors; development and standardization of salt-spray testing equipment; and continuation of tests to determine the life expectancy of pipe materials in service lines of the Bureau

Melting and Casting of Metals

Techniques were developed to permit the preparation of 5-lb ingots of the Bureau's "pure iron" without appreciable contamination. The ingots, which are to be used to study directly the properties of the elemental metal and its alloys, are of such high purity that accurate determination of the impurities constitutes a major problem. To meet the need for special refractories in which to melt this high-purity iron, an improved procedure for the production of beryllium oxide crucibles by slip casting was developed.

By melting and casting copper-tin alloys in a high vacuum, the Bureau developed metal with tensile properties definitely superior to those of the same metal melted in air and deoxidized by conventional practices.

Additions of less than 0.5 percent of boron to gray cast iron were shown to have a pronounced effect on the surface hardness and structural characteristics of the iron. Progress was made in the experimental production of gray cast iron in which the graphite is present in nodular form instead of the usual flakes. Cast iron with a transverse strength of 160,000 lb per sq in. has been obtained in this way, but the mechanism of nodular development has not as yet been determined.

Failure of Metals in Service

The failure or fracture of metals by fatigue under alternating or fluctuating stresses occurs in two stages: (1) The development of a tiny crack or cracks within the metal and (2) the gradual growth of the crack until the material is so weakened that complete rupture occurs. Current work in this field at the Bureau is concerned with the first stage of fatigue. It has been found that bending (prestressing) 24S-T aluminum at relatively low stress materially improves the fatigue strength at higher stress levels. In another phase of the investigation, X-ray diffraction studies showed that progressive changes in the strained lattice structure occur with increasing cycles of stress up to fracture. Attempts to correlate these observations with the origin and progressive development of fatigue cracks are in progress.

A study of the effect of chromium plating in reducing the fatigue limit of aircraft steels, requested by the Bureau of Aeronautics, Department of the Navy, was completed. In some instances the fatigue limit of steel was reduced more than 50 percent by plating the steel with chromium. The results show that the fatigue limit of plated steel can be improved by proper

heat treatment, but no procedure has yet been found to eliminate all effects of the plating operation.

Studies of failures in welded ship plate were continued, with the support of the Ship Structures Committee, representing the Army, Navy, Coast Guard, Maritime Commission, and American Bureau of Shipping. Recent results confirm previous conclusions that the fractures originate at notches or sharp changes in section, that the fractures propagate readily in plates which are notch-sensitive, and that specifications for ship plate should be revised to include a notch-senstivity factor since all of the cracked plates so far examined have complied fully with the requirements of current specifications.

Failed parts from transportation equipment were subjected to careful investigation to determine possible causes of failure. Parts from 17 aircraft which had failed were examined during the year for the Civil Aeronautics Board, Civl Aeronautics Administration, and Bureau of Aeronautics (Department of the Navy). Several of these failures resulted from fatigue failures of vital parts. Four bus and truck failures were also examined for the Interstate Commerce Commission, and two failures of ship parts for the U. S. Coast Guard.

10. Mineral Products

More than 60 individual research projects were under way in the separate but closely related fields of porcelain, pottery, glass, refractories, enameled metals, building stone, concreting materials, lime, and gypsum. As these nonmetallic, inorganic mineral products are very similar in composition and constitution, fundamental knowledge of their constituents can be effectively applied to many specific products. To obtain such information, basic investigations of the chemical composition, constitution, and structure of the substances which make up these materials were carried out, and fundamental constants such as thermal expansivities and specific heats of crystals and glasses were determined. Important studies concerned the behavior of mineral products under conditions of temperature and pressure which might be encountered during fabrication or use. Studies of the resistance of inorganic, nonmetallic structural materials to weathering, cleaning, and other chemical action were also carried out, and the physical and chemical conditions required to synthesize large inorganic crystals for electrical and optical purposes were investigated.

Synthetic Mica

The National Bureau of Standards, with the cooperation of the Office of Naval Research, has been conducting a program of crystal synthesis to determine the basic conditions necessary for the artificial crystallization of technically useful silicates, such as mica and asbestos, as well as other high-temperature inorganic compounds. Over 75 percent of the strategically im-

portant mica and asbestos are imported. New products and new uses of these minerals put a greater dependence on foreign sources. Thus, in time of emergency the production of synthetic minerals having essentially the same properties as the natural minerals may become highly important.

While the United States is the world's largest consumer of mica, it produces normally only 15 to 35 percent of its requirements of sheet mica and less than 5 percent of its requirements of mica splittings. No other mineral or substitute has yet been found that has the electrical insulation property of the natural micas. However, in the past year a synthetic mica having essentially the same properties as its equivalent natural mica was successfully crystallized at the Bureau. One property that may make the synthetic mica superior to the natural material is its ability to withstand much higher temperatures before it breaks down structurally. The crystallization of other silicates, especially amphibole and chrysotile asbestos, has also been actively studied with promising results.

Ceramic Coatings for Jet Engines

A project is under way, sponsored by the National Advisory Committee for Aeronautics, for the development of high-temperature coatings to protect metals and alloys used in jet engines against rapid deterioration from the effects of the hot gases. Coatings containing large percentages of refractory metal powders blended with a ceramic glass have been developed. When such coatings are matured by heating to a high temperature in an inert atmosphere, a metallic-type bond forms between the coating and the base metal. The glass promotes the formation of the metallic bond layer and also promotes a welding together of the individual metal particles present in the coating mixture. The result is an interlocking metallic structure that firmly grips the ceramic coating material. A coating of this type applied to cobalt-bonded titanium carbide (a potential turbine-blade material) protected it against oxidation for 200 hours at 1,800° F.

Ceramic Dielectrics

A series of investigations on ceramic dielectrics was initiated by demands for materials applicable to miniature electronic devices for the Armed Forces. A direct result of these studies was a program for the fabrication of ceramic capacitors, sponsored by the Department of the Army. Three types of miniature capacitors have now been fabricated. Single-plate and tubular capacitors meet the specifications for shape, size, capacitance and temperature coefficient of capacitance set up by the designers of miniature equipment. Multiple-plate capacitors, assembled from thin plates of ceramic dielectrics, have high capacitance per unit volume. These plates, 0.003 and 0.006 inch thick, were made by a newly developed technique for dry-pressing and firing thin, flat ceramics. The Bureau's program on ceramic dielectrics has also resulted in materials applicable to many prob-

lems in very high voltage, X-rays, instantaneous photography, and other fields.

High-Temperature Phase-Equilibrium Studies

Methods employing the techniques of high-temperature phase-equilibrium studies have wide application in the development and improvement of many commercial processes. Such methods have long been in use for investigation of composition-stability relationships in the systems involved in portland cements, porcelains, glasses, glazes, and other ceramic products. The completed results are ordinarily available in the convenient form of phase diagrams which contain the essential information. In this work it is necessary to trace the compositions of curves or surfaces separating different primary-phase regions or defining other thermal relationships in the systems. Graphic methods of representation become difficult when the number of components exceeds three, and impossible when that number exceeds four. An analytic method, making use of parametric equations, was therefore developed by the Bureau in cooperation with the Portland Cement Association. These equations make it possible to trace the desired compositions in systems of any number of components.

Optical Glass

Investigations are under way to determine the physical and chemical properties of a large number of glasses of widely varied compositions. A study of a number of glass-forming systems has led to a better understanding of the nature and constitution of glass. These investigations have also furnished information that is of immediate value in many fields of glass technology. For example, studies of the durability of glass have been of value in designing optical glasses of satisfactory durability in service and also have been useful in preparing specifications for pharmaceutical and laboratory glassware. Studies of viscosity, surface tension, and other properties of molten glass have been used in determining schedules for melting optical glass. The information obtained is also of value in formulating techniques for various glass compositions in all fields of glasswork.

There has recently been a demand by the Armed Forces for very large optical elements for use in supersonic wind tunnels, large aerial cameras, and other applications. Where such elements could not be furnished in suitable quality by commercial firms, the Bureau has undertaken to supply them. Since long annealing schedules are required to obtain the necessary optical homogeneity in these elements, the data previously obtained in the study of crystallization temperatures and rates were essential for this work.

Durability of Building Stone

To study weathering processes on various types and varieties of stone, an exposure test wall was constructed at the Bureau. This wall contains more than 2,000 samples of stone, obtained from all of the States except 1 and

from 16 foreign countries. Two types of setting mortar were used, one in each half of the wall. Although the chief purpose of the wall is the study of actual weathering in relation to laboratory tests for durability, several structural features are being investigated. Color permanence and discolorations are being studied, and the value of three types of waterproofing is under investigation. An attempt is also being made to determine whether the combination of certain types of stones in a structure is detrimental to lasting qualities.

Flow Table for Cement Testing

The 10-inch flow table is an essential instrument in the testing of portland and masonry cements. Under earlier specifications for this instrument, the flow values secured with flow tables in different laboratories often varied—sometimes by as much as 30 percent. As a consequence, cement that would meet specification requirements in one laboratory might fail in another. Study of the flow table by the National Bureau of Standards in cooperation with the American Society for Testing Materials has now resulted in a far more rigid specification for its construction and mounting. The new specification has been tentatively accepted by the ASTM and is being favorably considered for promulgation as a Federal specification. The Cement Reference Laboratory, which is located at the Bureau and supported jointly by the Bureau and the ASTM, developed a mixture for use in calibrating the flow tables. The mixture is composed of specially ground silica sand and an appropriate, readily obtainable mineral oil. It can be used for many repeated tests, will retain its flow properties for at least a month, and has been successfully employed by cooperating laboratories in testing their flow tables and in adjusting tables and mountings for more satisfactory performance.

Vitrified China

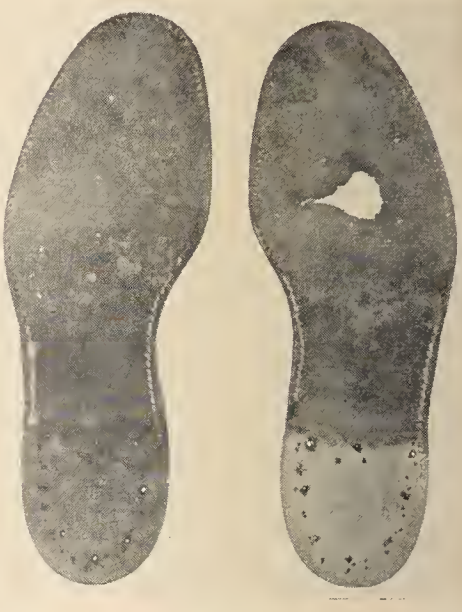
Investigations directed toward improvement in strength and wear resistance of vitrified china products are being conducted under the sponsorship of the Vitrified China Association. Effective progress in these studies has been made possible through development of standardized test machines at the Bureau. For example, refinements of two machines have resulted in standardization of tests for impact strength and chippage of chinaware.

A recent development is a machine for accelerated tests of the wearing qualities of glazes. Glazed plates strike and move over those to be abraded 128 times hourly while food-soil, a hot solution of detergent, and hot rinsing water are periodically introduced. After 48 hours of testing, the wear of the glaze appears comparable to that after 5 years of actual service. This machine assists in the evaluation of such factors as composition, fit, and bubble population with respect to glaze durability. Other factors pertaining to durability were revealed in a survey of plants where glaze

preparation was observed, and tests were made on glaze materials and batches.

Service Testing of Porcelain Enamel

Although the degree to which laboratory tests correlate with service data is a constantly recurring question in many fields of research, the difficulty of obtaining the needed information and the diversity of service conditions make even an approximate answer unavailable for numerous accepted tests. In the past, the Bureau has been instrumental in the development of a number of tests for porcelain enamels and enameled articles. Recently it began a study designed to compare the results of these and other laboratory tests with the service performance of typical enameled articles. Enameled facilities were installed at a series of public housing projects in geographic areas selected for the diverse characteristics of their local water supplies. Inspections were made during the year and will be continued at intervals to observe and record the effects of average home service. The results of these inspections will be compared with the results of a variety of laboratory tests on specimens duplicating those in service. The data obtained will be used in selecting those laboratory tests which best predict the resistance of enamels to deterioration in actual use.



Left: water penetration of leather impregnated with rubber by the Bureau's new process is tested dynamically by means of a specially designed machine. Right: the increased durability of the rubber-impregnated leather is shown by a service test in which the plain leather sole was worn away twice as much as the impregnated one (p. 43).

11. Building Technology

In addition to its function as a coordinating agency for the research and standardization activities at the Bureau relating to building constructions and equipment, the Bureau's Building Technology Division conducts a large number of investigative programs in the fields of fire protection, safety codes, heating, air conditioning, refrigeration, thermal insulation, masonry, reinforced concrete, and bituminous materials. Among the research and development projects completed during the year were those on properties of concretes containing commercial and experimental types of lightweight aggregates; fire resistance of walls of lightweight-aggregate masonry units; fire hazards and draft characteristics of masonry chimneys for houses; temperatures in a test bungalow heated by baseboard convectors; and the design, construction, and calibration of apparatus for measuring the thermal conductance of composite constructions and of refractory materials.

Subjects of other investigations initiated or continued include weathering of masonry; application of nondestructive dynamic tests to studies of materials; elastic and strength properties of concretes under dynamic loads; factors affecting the resistance of reinforced concrete beams to failure by diagonal tension; ignition temperatures of solids; effectiveness of flame-retardant chemicals and coatings; susceptibility of materials to spontaneous heating; intensity and duration of fires in ship staterooms; equipment for detecting and extinguishing fires; bituminous vapor barrier materials; weathering of asphalt coatings containing powdered mineral fillers; air filters; heating and cooling equipment for aircraft; grease filters; and thermal conductance of solids, liquids, and building constructions.

Reinforcing Bars for Concrete

With the completion of a preliminary study of the bonding efficiencies of reinforcing bars for concrete, a second program sponsored by the American Iron and Steel Institute was begun to develop technical information as a basis for specifications for reinforcing bars and to obtain engineering design data for the preparation of codes and specifications for reinforced concrete structures. The earlier research provided technical information which enabled manufacturers of reinforcing bars to ascertain which types of deformations not only could be produced economically but also would afford excellent resistance to slipping of the bars when embedded in concrete. The results showed that the bonding resistance was influenced by several factors, including the depth of concrete below the bar, bearing area and average height of the deformations, and the inclination of the bearing face of the deformations with respect to the longitudinal axis of the bar.

The results of this work are already influencing design practices. Concrete reinforcing bars of improved varieties are now readily obtainable by reference to specifications of the American Society for Testing Materials, which are based largely upon the data obtained in these studies; and commit-

tees of the American Concrete Institute are studying the data prior to the formulation of revisions of the building regulations for reinforced concrete. General application of the results will lead both to better performance of reinforced concrete structures and to significant economies in their construction and maintenance.

Heat Transfer in Buildings

Under the sponsorship of the Housing and Home Finance Agency, a new hot-box device was developed to obtain accurate information hitherto lacking on the heat transmission of wall, floor, and roof constructions containing air spaces and reflective insulation. This apparatus is specially designed so that specimens can be readily oriented in any desired position, thus permitting a more complete analysis of heat transfer through the air space within. After calibration of the apparatus, a frame construction containing an accordion-pleated reflective insulation was studied in a horizontal position with heat flowing downward and upward, in a vertical position with the heat flow horizontal, and finally inclined at 45° with the heat flowing upward and downward. Satisfactory results were obtained in all of these initial tests.

Fire Protection

Much of the information obtained in fire protection research is directly useful to authorities concerned with the development of codes and regulations for the construction and operation of ships, buildings, and similar structures. During the year, specimens representing 21 types of building constructions were tested as part of a long-range program to develop engineering design data. These included load-bearing walls, partitions, floors, and roofings. Ship constructions subjected to fire tests included two bulkhead and two deck constructions of aluminum, two steel deck constructions, one stateroom of lightweight hydrous calcium silicate material, and 14 deck finishing compositions. A study of the effectiveness of various flame-retardant chemicals and coatings was continued, as was a project directed toward improved measurement of the susceptibility of materials to spontaneous heating.

Thermal Conductivity at High Temperature

Apparatus was assembled for use in measuring the thermal conductivity of porous solids at high temperatures, and extensive research was conducted to verify the soundness of the design and to obtain quantitative data on errors of measurement. It was found that both the apparatus and the techniques developed were admirably suited for measuring the conductivities of refractory materials, rocks, and high-temperature insulations. The application of the equipment to granular materials was also made possible

by placing the materials in a shallow pan of nichrome. Measurements of thermal conductivities at mean temperatures from 400° to 1,200° F have now been made on a number of materials, including solid porcelain, granular bone chars, a magnesia insulating refractory, and powdered insulating materials.

Bituminous Vapor-Barrier Materials

At the request of the Department of the Navy, the Bureau has undertaken a study of bituminous vapor-barrier materials with a view to the selection of suitable coating materials to be used in conjunction with dehumidifying apparatus for the dehumidification of large storage warehouses. It is expected that it will be possible in this way to maintain the interior of warehouses at humidities low enough so that no special packaging of expensive equipment will be necessary. Approximately 50 representative coating materials are now under examination. Tests are mainly of the physical properties of dried films, with particular emphasis on the moisture-vapor permeability of unweathered and weathered films. All moisture-vapor permeability tests are made on free films of the coating materials.

Codes and Specifications

As a result of changing practices and the introduction of new materials, several important safety codes were in process of revision during the year. Cooperative work on development of recommended design practices for fire safety in Federal buildings to be erected in the future was carried on with other Federal agencies at the request of the Federal Fire Council. Federal practices were subjected to detailed study and group discussion in order to reach agreement on details of safe design for the wide range of buildings used by the Federal Government. The recommendations growing out of this work are expected to aid materially in reducing losses in personnel, records, and property.

In response to numerous requests from local committees, officials, and government agencies for information on how to put building codes on a sound technical basis, the Bureau revised its publication on the preparation and revision of building codes. Particular attention is given in this publication to the possibility of code improvement through the utilization of standards based on the results of laboratory research and on the composite judgment of experienced and competent specialists in their respective fields.

The results of many laboratory investigations at the Bureau provide information of much value to the small home owner who undertakes his own repairs. Realizing that the usefulness of these results could be greatly increased by presenting the essential facts in nontechnical language, the Bureau prepared a publication, entitled *Care and Repair of the House,* in which suggestions are presented for keeping a house and its equipment in good condition and for making repairs when necessary.

To study the mechanical properties of metals at low temperatures, a specimen is fully submerged (left) in a bath of liquid air. Changes in specimen diameter are followed accurately with the Bureau's new reduction-of-area gage (p. 46) as the specimen is extended to fracture. Right: fracture of a box girder at mid-span after test by the Bureau at 0° F (p. 34).

12. Applied Mathematics

The National Applied Mathematics Laboratories of the Bureau were established in recognition of the need for a centralized national computational facility equipped with high-speed automatic machinery, capable of providing a computing service for other Government agencies and staffed to undertake further development of electronic computing machinery. In this area the Bureau engages in basic mathematical research and in addition acts as a service organization, particularly in the fields of engineering statistics and quality control, for the Armed Forces, other governmental agencies, and industry. The work is organized in four sections: Institute for Numerical Analysis (at the University of California, Los Angeles), Computation Laboratory, Machine Development Laboratory, and Statistical Engineering Laboratory.

Numerical Analysis

Four principal lines of research relating to the numerical integration of linear and nonlinear second-order partial differential equations were pursued. These were (1) numerical methods in conformal mapping, (2) ordinary differential equations, (3) probability methods in numerical analysis, (4) miscellaneous studies in applied mathematics involving the applications and solutions of differential equations. Differential equations of this kind arise repeatedly in physics, but definitive studies as to the ap-

propriate way to solve such equations in the general cases have not yet been made. It is quite possible that, if optimum numerical methods are found for such problems, they will be applicable to higher-order differential equations of types which have so far evaded all attempts at solution.

Conformal mapping is a powerful tool for solving boundary value problems for plane regions, and some use of it is made in nearly every branch of classical applied mathematics. The work done on this subject during the year consisted largely of exposition and background research. A translation of an important collection of Russian papers on numerical conformal mapping, entitled "Conformal Representation of Simply and Multiply Connected Regions," was completed; an extensive bibliography containing many rare items was compiled; and a symposium on the construction and applications of conformal maps was held. The bibliography and the proceedings of the symposium will be published by the Bureau.

The most important project relating to ordinary differential equations was the preparation of a monograph on their numerical solution. At the end of the year about 90 percent of the material for this treatise had been assembled, and about 20 percent of the final manuscript had been completed. In connection with the monograph, a number of research studies were carried on relating to techniques for numerical integration of simple systems of ordinary differential equations. For example, a very general theory of the remainder terms in all forms of linear approximations was developed, and a new method for the numerical integration of ordinary differential equations was worked out which appears to possess rather outstanding advantages when applied to certain types of equations. Considerable attention was also given to the determination of the eigenfunction and eigenvalues of linear differential equations, and a new method for determining eigenvalues was developed which seems to be much better than the older methods in the literature.

Studies of probability methods centered on "stochastic processes" and their applications. A stochastic process can be described mathematically by a random variable (that is, a variable whose values follow a probability distribution) which depends upon time—for example, the numbering of calls entering a telephone switchboard in a given time interval or the turbulence of a fluid in motion at a given time.

Mathematical Tables

Much of the work in mathematical computation involved the tabulation of the values of fundamental mathematical functions which are encountered in a variety of physical and mathematical situations. Preparation of 12 basic mathematical tables was continued from the previous fiscal year, and two more were initiated during the year under review. The two new ones were a radix table for calculating logarithms to many decimal places and a table of zero and weight factors of the first 16 Hermite polynomials, which has important applications in the numerical solution of integral equations.

A table of Bessel functions $Y_0(z)$ and $Y_1(z)$ for complex arguments was completed and accepted by Columbia University Press for publication. Tables for X-Ray diffraction analysis were completed and were being made ready for publication in the NBS Applied Mathematics Series. Tables of Coulomb wave functions, a table of antilogarithms, a volume of tables relating to the Mathieu function, and a table of the exponential integral for complex arguments were nearing completion at the end of the year.

Statistical Engineering

The program in statistical engineering is concerned with the application of modern statistical inference to complex engineering experiments and sampling problems and with the analysis of data arising in physical experiments. As in previous years, the research projects in this field were concerned principally with the theory of small samples. This was to be expected, for very small sample sizes must often be used in experimentation in the physical sciences and in engineering testing. Whereas in previous years work was limited entirely to the consideration of samples formed from sequences of independent observations, some attention was directed this year to the properties of samples built from sequences of serially correlated observations, and a monograph was prepared on stochastic (random) processes from the viewpoint of mathematical statistics.

13. Electronics

In electronics the Bureau carries on research relating to electronic materials and methods as well as pioneering development work on the frontiers of applied electronics. New and highly specialized types of electronic circuits and components are developed to meet the particular requirements of industry and national defense. Much of the work is classified and involves the development of new ordnance devices for the National Military Establishment; a large part of the remainder consists of projects in basic and applied electronics conducted primarily for other Government agencies.

During the past year, the work in electronics included investigations of the fundamental behavior of cathodes and gases in electron tubes; development of testing and evaluation procedures for electron tubes; development of special-purpose electron tubes; investigations in circuit miniaturization, embracing printed circuitry as well as the use of subminiature components; design and development of components for electronic digital computing machines; and design and development of electronic instrumentation for remote indication of steam turbine clearances and temperatures, the telemetering of information on the stresses encountered in parachutes, and the measurement of air turbulence in wind tunnels.

Electron Tubes

Rugged electron tubes are indispensable wherever electronic equipment is used under severe conditions of vibration, shock, or acceleration. In airline service, for example, tubes in radio or in blind-landing devices must withstand the vibration of motors, air bumps, and landing shocks. Because of the importance of reliable tubes of this type in civilian as well as military use, a comprehensive tube-ruggedization program was initiated during the past year. A laboratory was installed containing a variety of vibration and impact equipment, and suitable test procedures were evolved for testing tubes under vibration conditions and for examining mechanical resonance effects.

Improvement of tube quality is dependent on a better knowledge of the properties of materials used as tube components, particularly the electron-emitting properties of cathodes. To this end, the emission properties of oxide-coated cathodes in which an alloy of nickel is used as the base metal are under investigation, with emphasis on determination of the effect of slight changes in the composition of the nickel alloy. Studies of the diffusion of magnesium through nickel were made, and a suitable test procedure for evaluating cathode performance was developed. The latter study has served to emphasize the strong dependence of cathode performance upon conditions existing in other parts of the tube and has led to the development of a test diode which will permit control of these conditions.

Electron tubes filled with a noble gas such as argon, neon, or helium are now widely employed in many kinds of electronic equipment. Since gas density is independent of temperature, gas tubes have a distinct advantage over those filled with a metallic vapor such as mercury, where the electrical characteristics change with the thermal variations in vapor density. On the other hand, the life of gas-filled tubes is limited by the tendency of the filler gases to disappear inside the tube during operation. An investigation of this "clean-up" phenomenon, using a helium-filled tube with a tantalum electrode, has led to the tentative conclusion that clean-up is the result of the bombardment of a negative electrode by high-velocity gas ions which penetrate the surfaces and become permanently trapped. Present work is directed toward demonstrating the reversibility of this effect—i. e., toward effecting complete recovery of the trapped gas from the cathode.

Electronic Miniaturization and Printed Circuits

In a program of electronic miniaturization, sponsored by the Bureau of Aeronautics, Department of the Navy, production designs were completed for three specific units of subminiature electronic equipment adaptable to manufacture by commercial mass-production methods.

The first unit is a high-gain wide-band intermediate-frequency amplifier of radar type. Final designs and model lot production were completed on this amplifier, which is only one-fourth the size of the original full-scale

Synthetic mica (bottom), with essentially the same properties as natural mica but able to withstand much higher temperatures, was successfully crystallized at the Bureau (p. 48) by melting a mixture of quartz, magnesite, bauxite, and a fluorosilicate compound in an electric furnace (upper right) at a temperature of nearly 1,400° C. Upper left: flakes of the synthetic mica are examined under a microscope for structural defects.

assembly but provides the same electrical performance. The unit contains 11 tubes and has a total volume, including case, of less than 11½ cubic inches. The second unit is electrically equivalent to the amplifier described above but uses printed circuits to the greatest practical extent. This emphasis on printed circuits is expected to result in increased production speed, reduced requirements for skilled labor and critical materials, greater uniformity of production, and lower cost per unit. Printed circuit techniques were found usable throughout, except for the intermediate-frequency coupling transformers. Two basic novelties were featured in the design: the printing of circuit components on cylindrical surfaces and the use of multilayer printing.

The third unit is a miniature self-contained battery-powered radio transceiver for use by the Navy in rescues at sea. Design of this unit is very nearly complete, and an initial model, fully meeting the functional requirements, has been constructed. It has a volume of 46 cubic inches, including a battery pack to provide 20-hour operation.

The principal advances in printed circuit techniques took place in connection with the subminiature printed intermediate-frequency amplifier. A rotary printer was designed and built for applying printed circuits on cylindrical surfaces. Additional experimental work was carried out on the decalcomania method of applying printed circuits. Resistors for use in printed circuits, applicable by the silk-screen process, were developed from formulations based on melamine-alkyd resin combinations with high-pH carbon blacks and suitable dispersing agents. These resistors have low-noise and low-temperature coefficients over the range −60° to +85° C. The resistance range from 1,500 ohms to 1 megohm has been covered thus far. Several formulations were also developed for adhesive-tape resistors having exceptionally low minimum values and good stability over ambient temperatures up to 200° C. Operation of components at these temperatures is essential in the most advanced miniature designs because of the high density of the heat-producing elements, such as electron tubes and resistors.

Electronic Instrumentation

In the program of electronic instrumentation for use in marine engines, sponsored by the Bureau of Ships, Department of the Navy, significant progress was made on several projects. Primary emphasis was directed toward the development of noncontacting electrical precision indicating devices to measure clearance between stationary and moving parts at several critical points within the steam chest of marine propulsion turbines. Because of the more rigid requirements imposed upon propulsion turbines by modern naval operation, an exact knowledge of clearances within the turbines under extreme conditions of operation has become necessary. Instrumentation providing the required performance was achieved by an application of the electronic micrometer, developed at the National Bureau

of Standards last year on the same instrument program. Seven different position indicators were designed for operation at the several positions of interest inside the turbine and its power-transmission gear. These units provide the requisite resistance to mechanical shock and vibration and to contact with superheated steam, hot oil, oil splash, and vapor. Two of these devices have been in use aboard ship throughout engineering-test cruises, providing new information of importance to the operation of the Fleet. A large-scale instrument system, including 14 position indicators of several types, has been designed and is in the process of fabrication and proof test. During the coming year this system is scheduled for installation in an experimental marine turbine at the Naval Boiler and Turbine Laboratory.

Two instruments were developed for measuring the thickness of lubricating oil films in sleeve-type bearings. The first model, having a full-scale range of 0.006 inch and including cathode-ray oscillographic presentation for fast response, was completed and installed in the Engineering Experiment Station of the Bureau of Ships. On the basis of experimental results obtained with this equipment, a second model was developed, providing a 10-fold increase in sensitivity and considerable reduction in the size of the electronic micrometer input elements. Laboratory development has now been completed on a third model instrument which uses a novel type of null-balance iron-core input element to obtain several improved operating features.

A Diesel crankshaft instrument was designed for simultaneous indication of film thickness and shaft vibration from any two of 14 points of measurement in the crankshaft bearings. Installation of this equipment at the Engineering Experiment Station is planned for the coming fiscal year.

Development work was completed on three progressively improved systems for multipoint temperature measurement on a high-speed rotating system without the use of contacting commutators. Since these systems are primarily adaptable to sensory elements of the resistance thermometer type, future development will be directed toward the achievement of improved subminiature thermometer elements and methods of mounting them on the blades of gas turbines in turbo superchargers.

Parachute Telemetering Unit

Under the sponsorship of the Bureau of Aeronautics, Department of the Navy, a low-cost, expendable unit for telemetering functional data from a descending parachute to a remote ground station was developed for use in studies of parachute design.

The project involved the design and construction of measuring equipment, a miniature transmitter and coder, and ground stations to receive the information. The expendable unit, which will cost less than $300, has seven information channels and an eighth channel for synchronization. It

measures and telemeters to ground such data as rate of descent, stress and strain in body harness and shroud line, opening shock impact, and parachute oscillation. Design of all components of the parachute-borne units, as well as the required ground stations, is complete. Initial drop tests have been made, and full-scale proof tests by the sponsoring agency are projected for the near future.

Characteristics of Electrocardiographs

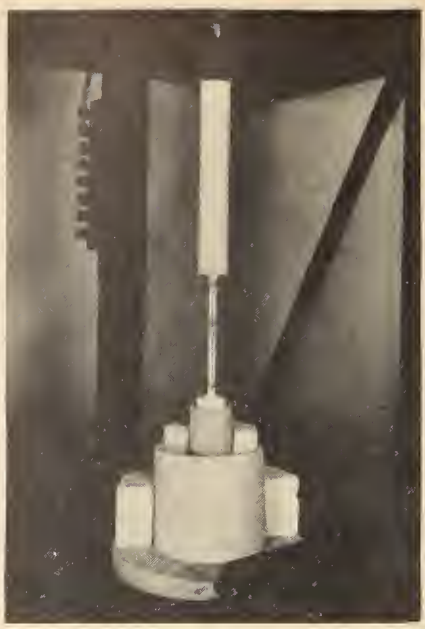
At the suggestion of the Veterans' Administration, a study was undertaken to determine the adequacy of commercially available electrocardiographs for recording the electrical signals derived from the beating of the heart. This program has included three major phases: (1) Determination of the instrument characteristics of commercial electrocardiographs in order to establish the fidelity with which their recording patterns correspond to the electrical signals they receive, (2) determination of the true characteristics of the electrical signals developed by representative "normal" and "abnormal" hearts, and (3) establishment of the significance of distortions imposed upon the true cardiac signal with regard to its usefulness as a basis for clinical diagnoses.

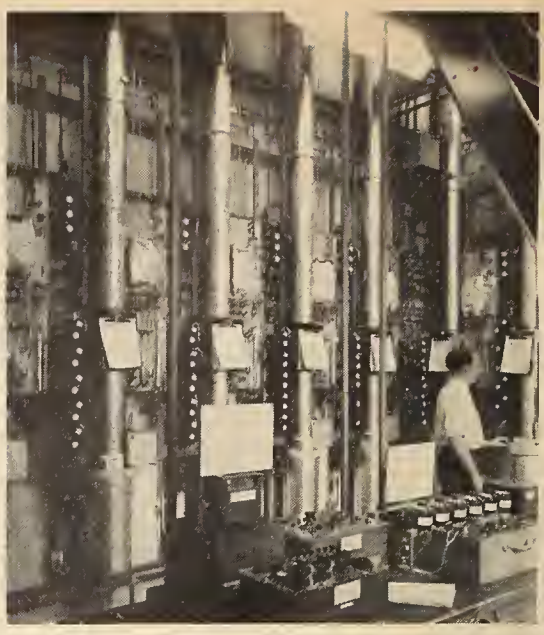
Phases (1) and (2) have been very nearly completed; phase (3) is scheduled for attention during the coming year. This work is of direct importance in providing a quantitative basis for specifications to be used in the Government's procurement of electrocardiographic equipment. It will also aid scientific research in cardiography by providing an initial step toward the standardization of electrical characteristics of cardiographic recorders and the recordings which they provide.

14. Automatic Computing Machines

The Bureau's Applied Mathematics Laboratories and its Electronics Division are jointly conducting an extensive computer program, undertaken in cooperation with the Office of Naval Research, the Bureau of the Census, the Department of the Army, and the Department of the Air Force. This program involves the research, design, and development work necessary to produce electronic machines that will perform, upon instruction, predetermined sequences of calculation running into the thousands of operations without the intervention of human operators. The result will be the solution in a few hours of complex problems in atomic physics, ballistics, and aerodynamics which cannot now be solved except by simplifying assumptions and thousands of man-days of work. The rapidity with which numerical data can be handled, classified, and analyzed will also be correspondingly increased.

These new large-scale electronic computing machines are being eagerly awaited. However, because of their complexity, their construction is a long-range project. Meanwhile, by scaling down certain features of a larger





A specimen prepared from one of the special high-temperature ceramic bodies developed by the Bureau is shown (left) in position for creep tests (p. 49). Eighteen-foot distillation columns (right), used in the separation of hydrocarbons from petroleum at the Bureau, are operated 24 hours a day throughout the year (p. 30).

machine, such as the high-speed memory, the Bureau expects to assemble within a reasonably short time a machine capable of solving many of the less complicated problems that continually arise in scientific work. Construction of this machine has now progressed through the preliminary design and layout stages. It will be a serial-type computer, with a 1-megacycle repetition rate, and will use an acoustic delay line type of memory. It will also have provision for the addition of an electrostatic memory. The new high-speed machine will perform a substantial portion of the computation work of the Bureau's laboratories, solving many problems until recently considered impossible of solution. It will also aid in computing machine development at the Bureau and will provide important training and operational experience for personnel of those agencies that plan to operate the more complex electronic computers as soon as their construction is complete.

The Department of the Army has arranged for the Bureau to act as consultant and design agent for a large-scale electronic digital computer which the Army expects to construct for its own use. Much of the general design experience and component development for the Bureau's computer is directly related to the detailed design of this larger machine. Both machines will have the same logical structure, which is based on a serial system using an acoustic delay line memory.

To meet the urgent computational needs of the aircraft industry and Governmental missile research and testing centers on the West Coast, construction of a modest-scale electronic digital computer has been undertaken at

the Bureau's Institute for Numerical Analysis in Los Angeles, Calif., with the support of the Air Matériel Command. The logical design of the INA Computer has been completed and laid out in block-diagram form. The high-speed internal memory, which will be of the electrostatic-storage type, is in the prototype-testing stage of development. The computer design has been planned so that an intermediate magnetic-drum memory, of relatively high-storage capacity, can be readily incorporated into the machine. The detailed design specifications for the arithmetic and control units are now complete, and construction of these major components of the computer has begun.

In addition to the machines under construction for its own use, the Bureau is acting as the procurement and testing agency for five machines for other Government agencies. A contract for three of these machines (one each for the Census Bureau, the Army Map Service, and the Air Comptroller) was let during the year. The contract calls for delivery of the first of these machines by February 1, 1950, but difficulties encountered in design of the machine will probably require postponement of this date. A contract for a fourth machine, supported jointly by the Navy and the Air Force, was let to another contractor with delivery scheduled for July 1, 1951. The contract for the fifth machine, which is for the Office of Air Research, is in the negotiation stage.

15. Radio Propagation

The Central Radio Propagation Laboratory of the Bureau is the primary agency of the United States Government for the coordination and centralization of information on research in radio wave propagation. The laboratory is also assigned responsibility for development and maintenance of the national primary standards for electric quantities at frequencies above 10 kilocycles per second.

Comprehensive programs of basic and applied research are undertaken in radio physics and associated geophysical phenomena of the upper atmosphere and the troposphere. Extensive laboratory studies are also under way dealing with properties of matter at radio and microwave frequencies and the development of techniques for precise measurement of electric quantities in this region. In addition to such research activities, the Bureau does a large amount of advisory and consulting work on radio for other agencies of the Government such as the National Military Establishment, the State Department, and the Federal Communications Commission, and participates in an advisory capacity in international radio conferences.

The work in radio propagation is divided into three branches: The Ionospheric Research Laboratory, the Systems Research Laboratory, and the Measurement Standards Laboratory. The Ionospheric Research Laboratory carries out basic research on the nature of the upper atmosphere and its ability to reflect radio waves. The Bureau maintains a widely

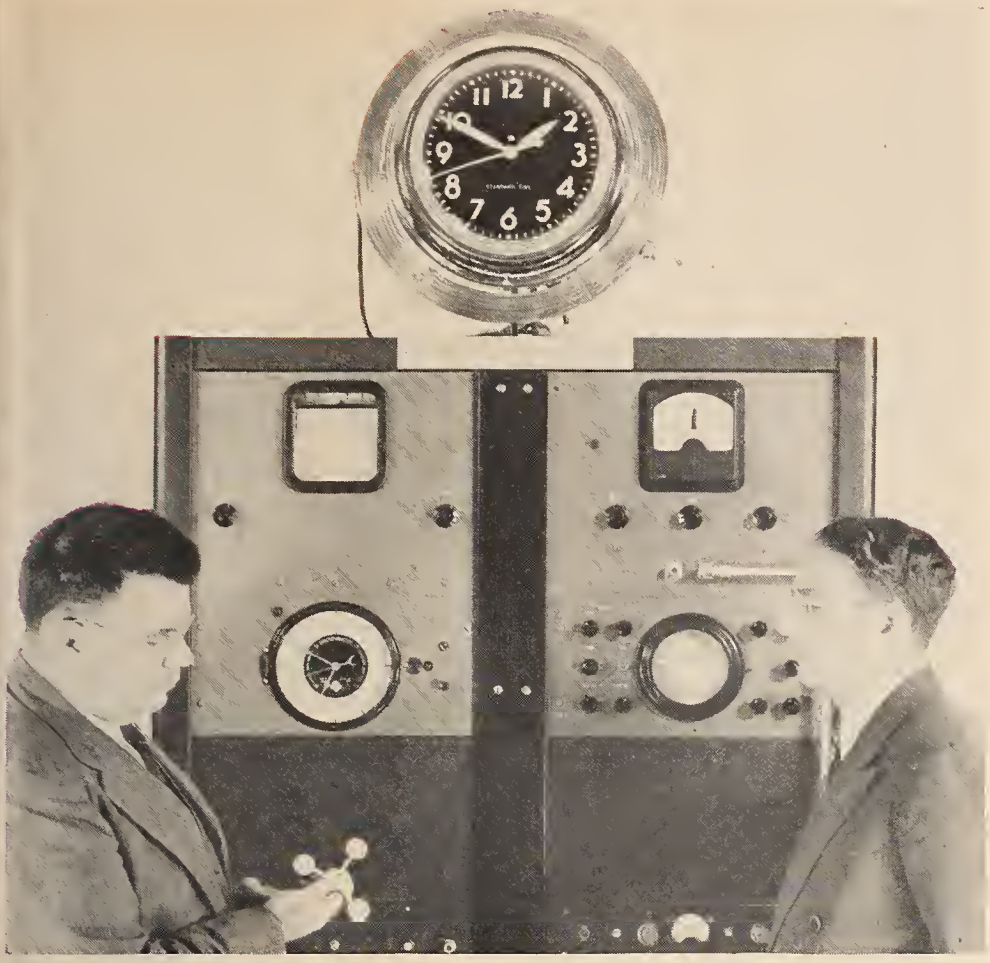
separated network of 14 ionospheric sounding stations extending over the American continents and the Pacific area, the largest network operated by any one government. Seven of these stations are controlled directly; the other seven are operated in close cooperation with other agencies. Data supplied by these observatories provide basic material for scientific research and for determining frequencies to be used in long-distance radio communication. In addition, a radio propagation field station is operated at Sterling, Va., for performance of special experiments. Because of the important influence of extraterrestrial effects on ionospheric phenomena, solar and cosmic phenomena are studied. These include radio waves emitted by the sun and other celestial bodies, which also afford a new means for exploration of the universe.

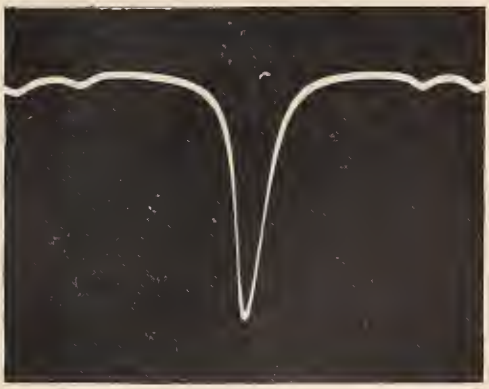
The Systems Research Laboratory applies radio propagation information to the practical problems involved in such uses of radio as communication, navigation, and traffic control, with particular consideration to the advantages and limitations of the types of radio systems concerned. It prepares and publishes a monthly series of charts predicting, three months in advance, the best frequencies for long-distance communication throughout the world. These charts are based on data collected by the network of field stations and by agencies of other national governments. It also conducts research in propagation at frequencies in the VHF and UHF bands which are not reflected by the ionosphere. This part of the program was greatly expanded during the past year because of increasing public demands for FM and television service, increasing use of the higher frequencies for air-to-ground work, and the consequent need for allocation of frequencies on an efficient engineering basis.

The Measurement Standards Laboratory conducts research in methods for measuring electric quantities at radio and microwave frequencies. Advances of the last few years have carried this work to higher and higher frequencies, across the border where classical electromagnetic theory and quantum theory overlap, and have opened up a new field of basic research in physical science. An important function of this laboratory is the maintenance of standards of electric quantities at these frequencies, including time and frequency standards which are broadcast continuously from the Bureau's radio station, WWV, at Beltsville, Md., and from an experimental station, WWVH, at Maui, T. H.

Atomic Clock

An atomic clock, based on a constant natural frequency associated with the vibration of the atoms in the ammonia molecule, was developed, providing a new primary standard of frequency and time. Invariant with age and independent of astronomical observations, the new clock promises to surpass by one or two orders of magnitude the accuracy of the present primary standard, the rotating earth. This, the first atomic clock ever built, is controlled by a constant frequency derived from a microwave





The atomic clock (top) developed by the Bureau (p. 66) provides a new primary standard of frequency and time invariant with age. Lower left: drawing of the ammonia molecule whose microwave absorption line (lower right) provides the invariant frequency that controls the timekeeping of the clock. The ammonia gas is maintained in the 30-ft absorption cell wound around the synchronous clock above the panel.

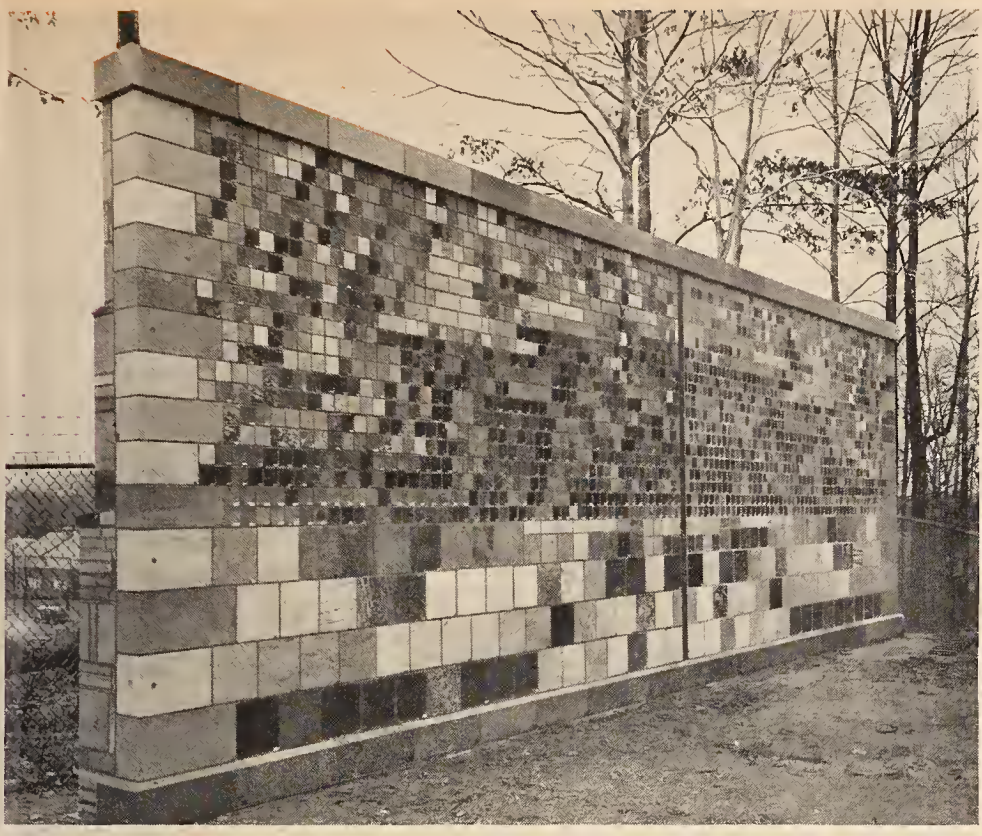
absorption line of ammonia gas and has a time constancy of 1 part in 20 million. Theoretical considerations indicate a potential accuracy of 1 part in a billion or even 10 billion, depending on the type of atomic system and spectrum line used.

The present crowding of the radio frequency spectrum has imposed severe limitations, both nationally and internationally, on the expanding use of radio for industry and communications. The present allocation of radio channels allows for a drifting of each station's frequency, so that a broad channel is required if interference with other stations is to be avoided. The maximum utilization of available space in the radio spectrum depends on the accuracy with which the frequency of an individual station can be controlled, especially at the higher frequencies where quartz crystals cannot be used as frequency controlling elements. These frequencies, used by radar, television relays, and microwave equipment in general, could be controlled by atomic elements, permitting a more economical assignment of spectrum space. Such control would also make possible the permanent establishment of radio channels on such an exact basis that tuning would be made as automatic as the dialing of a telephone number.

The improvements in frequency and time measurement offered by the atomic clock are also of fundamental importance in many fields of science. An absolute time standard will be of special importance in astronomy, where present time standards leave much to be desired. The atomic clock and the method represent important tools of research and development in every technical field where precise measurements of time and frequency are crucial—for example, in long-range radio navigation systems, in the upper range of the microwave region where atomic systems can serve as electronic components, and in basic research in microwave spectroscopy and molecular structure.

The present time and frequency standards are based on astronomical determinations of the period of rotation of the earth. However, the earth is very gradually slowing down in response to the forces of tidal friction in shallow seas. In addition, there are irregular variations—some of them rather sudden—in the period of rotation, the reasons for which are unknown. These two causes are responsible for changes in mean solar time and therefore in the frequency of any periodic or vibrating systems measured in terms of such time standards.

In recent years, vibrations of atoms in molecules—or what are more specifically termed spectrum lines originating in transitions between energy levels of these atomic systems—have been found in the microwave region of the radio spectrum. It has been possible to make very precise measurements of these lines by radio methods using all-electronic equipment of unprecedented sensitivity and resolution. When it became evident that such spectrum lines might eventually provide new primary frequency standards, the Bureau began seeking a means of utilizing one of these lines to control an oscillator which in turn could be used to drive a clock. Be-



An experimental masonry wall containing over 2,000 specimens of stone has been erected at the Bureau for studying the weathering of building stone. Forty-seven States and 16 foreign countries are represented. The wall was designed so that all phases of the weathering process on numerous varieties of stone could be studied in the one structure.

cause the resulting equipment, the atomic clock, is controlled by the invariable molecular system of ammonia gas, it provides an atomic standard of time analogous to the Bureau's new atomic standard of length, which is based on the wavelength of green light emitted by a single mercury isotope.

Microwave Standards

A survey was made of errors in measuring impedance with slotted coaxial lines and standing-wave ratio methods. Techniques were developed, using the best coaxial lines available in the country, which gave results practically independent of all instrument errors except those in the line itself. Considerable progress was made on design, test, and procurement of vertical air-dielectric slotted lines having known dimensions uniform to 0.1 percent or more. These are to serve as primary standards of impedance and as useful standards in measuring power attenuation and voltage.

Field-intensity standards were developed for the very-high-frequency band at intervals of 25 megacycles. Intercomparison of the "standard field" and "standard antenna" methods of measuring field intensity gave agreement to a few percent.

Quartz-crystal frequency standards and associated monitoring equipment were improved. Such oscillators showed relative constancy within 4 parts in 10 billion for intervals up to 10 hours. Initial measurements on improved quartz-crystal units indicated that a tenfold increase in quality factor and long-interval constancy can be expected.

The theory and design of an electrodynamic radio-frequency ammeter to serve as a primary standard was completed, and correction formulas for improving accuracy in studying solid dielectrics were derived. A very sensitive microwave instrument was developed to measure and make a continuous record of the dielectric constant of matter as a function of time. Not only is this instrument a basic research tool for investigating phenomena causing changes in the dielectric constant of matter, but it also can be applied to the problem of industrial production control.

Ionospheric Research

Because of the pronounced influence of the sun on the state of the upper atmosphere, extensive investigations were made of various measures of solar activity, including sunspot numbers, sunspot areas, "plages," and coronal intensities. Also under way were studies of the intensity of radio waves generated by the sun. Known as "solar noise," this phenomenon is a possible index of solar activity. For these studies, two solar radiometers were constructed and placed in continuous daily operation throughout the daylight hours, one operating on 480 megacycles and another on 160 megacycles. An outstanding event of the year was the observation of an unusually intense outburst of solar noise which was accompanied by a simultaneous fade-out of all high-frequency radio signals propagated by the ionosphere and a flare of bright hydrogen light from a group of sunspots. If all of the solar noise outburst is assumed to come from the suspected area, then the intensity of radiation from this area during the burst was two million times the average intensity from the rest of the sun's visible surface.

The variability of the ionosphere was studied at a number of stations by determining the variance (mean square deviation) of various parameters, such as the critical frequency and the maximum usable frequency affecting propagation. Results of these studies were applied by international conference groups in deciding on allocation of frequencies for high-frequency broadcast services. Future work in this field is being facilitated by direct transfer of the raw ionospheric data to punch cards for automatic machine calculation of the necessary statistics. The punch-card techniques will also permit economical tabulation and publication of the collected data for the use of scientists in other research organizations.

Short-term fading of vertical-incidence signals, studied by means of instantaneous values of field intensity recorded at 15-second intervals, indicated differences between the ionosphere in the daytime and at night. During the night adjacent 15-second values were found to be independent of each other, but during the day pronounced autocorrelation was observed.

This was interpreted as due to the smoother characteristics of the equivalent reflecting surface of the ionosphere during the day.

Observations were made of round-the-world delayed signals at very low frequency (18 kc). Measurements of the differences between the times of arrival of the "direct" and "round-the-world" signals showed clearly that this frequency is propagated by multiple reflections between the earth and the lower ionosphere, and not the surface waves over the earth or beneath the ionosphere as has been supposed by some investigators.

Additional information about the upper atmosphere is being derived from radio reflections from meteor trails. Data have been obtained which refute the views previously held by many investigators that meteors are largely responsible for sporadic-*E* reflections. An expanded operational program for the systematic observation of meteor counts on the approximate frequencies of 13 and 27 megacycles was begun during the year, and a photographic recording system was completed for the simultaneous counting of meteors on several frequencies. Because meteors travel through the atmosphere at velocities about 100 times that of sound, much basic information in the field of hypersonic physics may be derived from their study.

Tropospheric Propagation

The major factors influencing propagation at microwave frequencies are tropospheric meteorological effects and terrain geometry. A significant meteorological effect for very short microwaves is attenuation due to rain. During the year an extensive investigation of the expected magnitude and occurrence of serious rainfall attenuation over typical microwave relay paths was completed. These studies have received attention from both industrial and military groups as a result of the wide expansion of microwave-relay applications.

Experimental measurements were made of the diffraction of microwaves of 6-cm wavelength over screens of trees obstructing simple paths up to 3 miles long. The complex patterns of the received signal in the shadow region behind these obstacles contain deep minima resulting from interference between the direct wave and the ground-reflected waves diffracted over the trees. Heretofore, it has been customary to neglect the ground reflection at microwave frequencies. This investigation demonstrated the necessity for having adequate clearance over obstacles on microwave relay paths designed for maximum reliability.

In order to determine the changing meteorological factors at selected points along the path of observation in field-intensity measurements, a mobile van was equipped with apparatus for measuring pressure, temperature, and humidity which may be carried aloft by a wiredsonde balloon. This equipment is of a special lightweight design and includes the latest type of temperature and humidity elements developed at the Bureau. A special temperature and humidity chamber has been designed for field calibration of this equipment.

A theoretical study was made in an attempt to find a mathematically and physically plausible method for calculating the field strength of a transmitter in the presence of irregular terrain. For the problem of large irregularities such as smooth hills, an integral equation was proposed. To support its use, the integral equation was solved rigorously for two important special cases: a plane homogeneous earth and a spherical homogeneous earth. In both these cases the solution of the equation was found to agree essentially with the approximate solutions found by other more conventional means.

The variablity of refractive index with altitude is an important factor in determining propagation characteristics in the troposphere. A "microwave atmospheric refractometer" was therefore developed to measure instantaneously the index of refraction of the atmosphere over a small volume of space. This device consists essentially of two microwave resonant cavities, one of which is a standardized reference; the atmosphere is drawn through the other cavity, and the difference in the resonant frequencies of the two cavities is a direct measure of the index of refraction of the atmosphere. Correlation of the meteorological and refractive index data with radio field-intensity measurement is expected to yield an understanding of the basic factors influencing tropospheric radio propagation.

16. Testing, Calibration, and Standard Samples

The Bureau's testing and calibration activities are a natural outgrowth of its custody of the Nation's basic physical standards. In many cases master standards used in industry or by other laboratories must be checked periodically against these national standards. The Bureau is also responsible for testing many of the materials purchased by the Government to assure conformance with specifications. In the course of this work, many new instruments, new methods of measurement, and much technical data on the properties of materials are developed.

During the year, over 380,000 tests and calibrations were performed for other Federal agencies and laboratories and industries throughout the country. In the same time over 20,500 standard samples were issued by the Bureau.

Typical of the tests performed by the Bureau for the Federal Government is the testing of lamps. In the lamp-testing laboratory, 5,731 light bulbs, a sampling of 4,691,018 purchased by the Government this year, were life-tested. Other representative tests of this kind included the certification of 552 commercial standard cells; determination of hypo content in over 1,300 samples of film in order to insure permanency in archival film records; the sample-testing of 223,478 clinical thermometers for the Veterans Administration, the U. S. Public Health Service, and the U. S. Department of Agriculture; and the examination of 2,083 samples of bituminous materials to provide information for control of the quality of highway surfacings.

Left: test bungalow constructed at the Bureau for research in heat transfer phenomena in small houses. This bungalow has since been completely enclosed within an insulated enclosure (right) so that the temperature outside of the house can be maintained at any temperature condition encountered throughout the United States.

For many years, all radium preparations sold in the United States have been tested and certified by the Bureau as no commercial laboratory is equipped to do this work. During the year, 2,317 tests of such materials—principally medical preparations for hospitals and clinics—were made for the Government and private concerns. The Bureau also maintains the only X-ray laboratory in this country where calibration of radiation-measuring instruments in terms of roentgens is possible from 10 to 1,400 kv. Recent developments in atomic energy, providing opportunities for bodily injury due to excessive radiation, have made this calibration work increasingly important. Approximately 500 radiation-measuring instruments were tested for the Atomic Energy Commission to determine their calibrations in roentgens for different photon energies. Because of the urgent need for these instruments, which are used in personnel protection, they had been put in use without thorough investigation of their radiation calibration. Another important service is the measurement of the amount of radon in breath samples taken from persons working with radium and radium-luminous paint. This is necessary in order to detect ingestion of harmful amounts of radium in the body and to apply corrective measures before injury has occurred. The radon content of 729 such samples were determined for a number of Government agencies and commercial firms.

One of the largest testing projects is the cement-testing program, which is conducted to insure compliance of Government purchases with Federal specifications. About 7,000,000 barrels of cement were sample-tested during the year. The increase of approximately 2,000,000 barrels over the previous year was largely due to increased Federal construction. Both physical and chemical tests were performed on 19,234 samples of portland cement, comprising 94,081 separate determinations. The tests were carried out at six separate field stations established for this purpose as well as at the central laboratory in Washington.

Closely related to this work is the program of the Cement Referenee Laboratory, which inspects the apparatus and test methods of cement-testing laboratories. This laboratory is located at the Bureau and is jointly supported by the Government and the American Soeiety for Testing Materials. Field work of the laboratory ineludes demonstrations and inspections of test methods and cement-testing apparatus. During the year, 59 eement laboratories were inspected throughout the eountry. The Public Roads Administration contributes to the financial support of the project and requires that laboratories testing cement for Federal-aid projcets must be inspected regularly by the Reference Laboratory.

Standard Samples are materials that are certified for chemical composition or for some physical or chemical property, such as heat of combustion, melting point, or index of refraction. Standard samples of steels control the quality of the steel industry's output. Primary chemical standards and metals with certified melting points make possible uniform measurements of heat and temperature in the same way that standard weights provide uniformity of measure in buying and selling. Standard pigments define the colors of paints, and a large variety of hydrocarbons, supplied as single substances of high purity, calibrate the instruments that eontrol the composition of motor gasolines, aviation fuels, and synthetic rubber. The list of standard samples issued by the Bureau now includes 450 materials, 25 more than last year.

Electricity and Optics

In the electrical field, standards issued and materials tested included standard resistors, potentiometers, bridges, capacitors, inductors, ammeters, voltmeters, wattmeters, watt-hour meters, current and voltage transformers, insulating materials, magnetic test coils, standard samples of magnetic material, standard cells, and various types of batteries. For example, in the past year 552 commereial standard cells were certified; several thousand batteries of various types were also tested.

Optical standards prepared and issued included lamp standards of candlepower, luminous flux, and color; three types of standards for checking the photometric, wavelcngth, and reflectance scales of spectrophotometers; glass standards of transmittance for calibrating oil colorimeters; porcelain-enamel or glass standards of reflectance, opacity, and gloss. In addition, glass standards of chromaticity and luminance were under preparation for the television industry, and work was still in progress in preparation for the life-testing of fluorescent lamps. The testing of precision cameras and photographic lenses continued in large volume, both for Government agencies and for industry. Other tests involved telescopes, microscopes, binoculars, surveying instruments, and sight tcsters; windshields, goggles, and sunglasses; and the determination of refractive indices of optical glasses and synthetic crystals.

In photographic technology, over 1,300 samples of film were tested for hypo content in order to insure permanency in archival film records. Tests were also made of permanent record film, photographic chemicals, developers, and fixers; and a large number of sensitometric tests were carried out, principally for the Bureau of Federal Supply. A total of 560 microcopy resolution test charts, to be used in testing microcopying camera and film combinations, were furnished to various agencies.

Metrology

A major responsibility of the Bureau is the maintenance of the Nation's basic standards of physical measurement. This involves the testing and calibration of standard measuring apparatus and reference standards for precise measurement of length, area, angle, mass, volume, density, and similar quantities throughout the United States. During the year, 135,640 measurement standards were calibrated, certified, and sent out for service in laboratories, manufacturing plants, and commercial establishments.

Heat and Power

During the fiscal year, 188,335 separate determinations were made. A total of 3,382 liquid-in-glass laboratory thermometers, 105 resistance thermometers, and 351 thermocouples were calibrated; 223,478 clinical thermometers were sample-tested for the Veterans' Administration, U. S. Public Health Service, and the U. S. Department of Agriculture. Tests and calibrations of specialized thermometers and thermometric devices required, in many cases, special studies and the construction of appropriate apparatus. Examples were the tests and investigations made for the Air Matériel Command on experimental thermometers and temperature-control equipment for use in turbojet engines in high-speed aircraft.

Large quantites of very pure isooctane (2,2,4-trimethylpentane) and normal heptane were prepared for distribution as the ultimate primary standards for the octane rating of gasolines throughout the United States. Six hundred and fifty-seven standard samples of oils were supplied for the calibration of viscometers. Three hundred and eighty fuels and lubricants, 162 miscellaneous materials, and 25 oil filters were tested for compliance with Federal specifications. Seven hundred and forty-seven automotive spark plugs were tested for various Government agencies. Automobile gasoline economizers, gum removers, fuel improvers, and radiator antifreeze and antileak compounds were tested for the Federal Trade Commission and the Post Office Department for detection of fraudulent advertising. Forty-five tests on aircraft electrical network equipment were conducted for the Bureau of Aeronautics, Department of the Navy. These included qualification tests of circuit breakers; performance tests on a variety of experimental switches, relays, circuit breakers, and connectors; and examinations to determine the causes of service failures. Other devices

tested for Government agencies included armored cars, automobile speed governors, gasoline-dispensing pumps, automotive and aircraft electric cable, and model engines.

Atomic and Molecular Physics

The increasing use of radioactive isotopes in medical treatment and scientific research was reflected in the demand for radium D+E standards, radium gamma-ray standards, radon standards, rock samples, and radioactive cobalt 60. A total of 937 isotope samples were supplied on request. In addition, 2,317 tests were made on radium preparations sold in this country, 500 radiation-measuring instruments were tested for the Atomic Energy Commission, and 729 breath samples of radium workers were analyzed for radon content.

During the year, 219 analyses (909 determinations) were made in the mass spectrometer. Thirty-three standards of thermal radiant energy were calibrated and issued. Miscellaneous radiometric tests performed at the request of various Government agencies included calibrations of ultraviolet meters; tests to determine the output of germicidal and therapeutic ultraviolet lamps; determinations of spectral response and sensitivities of thermopiles, photoconducting cells, and similar devices; and determinations of infrared and ultraviolet absorption characteristics of protective eyeglasses, special plastics, and optical materials.

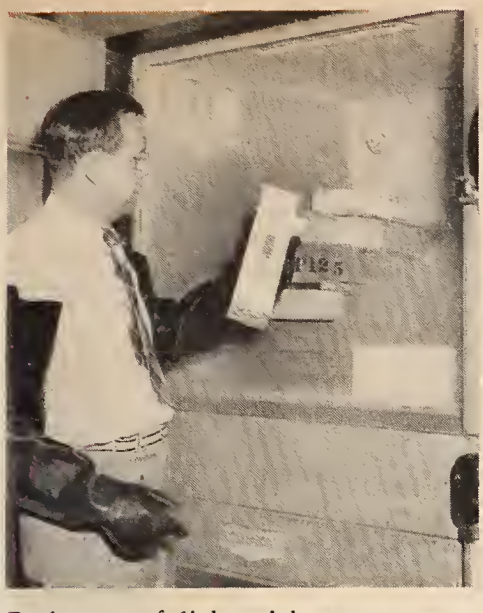
Chemistry

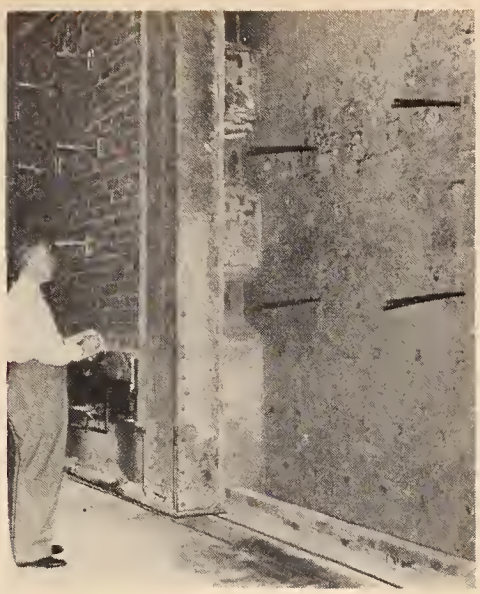
A large proportion of the samples tested or analyzed by this Division represented tests for conformance to Government commodity specifications. Included were about 850 samples of paints and varnishes, about 1,400 metal and alloy samples, about 1,500 samples for spectrochemical analysis, and nearly 2,500 raw sugar samples. This last group, which provides a check on the assaying of raw sugar imports, was approximately 20 percent larger than in the previous year.

As in other years, there was a considerable amount of nonrepetitive testing—the examination of special materials for other laboratories and agencies for purposes of identification, determination of impurities, or evaluation of quality. The Federal Trade Commission and the Quartermaster Corps of the Army were the largest users of this service. The analytical work performed during and since the war for the Manhattan project and the Atomic Energy Commission was terminated in April 1949, except for work of an umpire character, which will be continued.

Mechanics

There was again a pronounced increase over the previous fiscal year in tests made for Government agencies. The number of master beer meters tested increased from about 200 in 1948 to about 245 in 1949; an accurate





Resistance of lightweight-aggregate concretes to freezing and thawing cycles is determined (left) in this specially designed refrigerator at the Bureau. Right: a bearing wall of hollow brick is drawn into place in front of the Bureau's wall-testing furnace in preparation for a fire test (p. 54).

calibration of these meters is essential for the correct computation of Federal tax on beer, amounting to about $800 million per year. The number of elastic calibrating devices tested increased from 180 in 1948 to 221 in 1949; these devices are responsible for the accuracy of tension and compression testing machines and for the weighing of items ranging from airplanes to cattle. Tension, compression, bending, torsion, and hardness tests were made on about 1,200 specimens submitted by other Government departments, State institutions, and private organizations to determine mechanical performance and compliance with specifications; the corresponding figure for 1948 was 700. Tests for compliance with Federal specifications were made on 32 mechanical appliances, such as floor polishers, motion picture projectors, and numbering machines; vending machines were tested in connection with fraud cases; 50 oxygen regulators and associated apparatus were evaluated for the Bureau of Aeronautics, Department of the Navy; and 82 pressure gages and barometers were tested for Government agencies and the public. Barographs carried in 10 international speed, distance, and altitude trials of aircraft were tested for the National Aeronautic Association.

Forty airspeed measuring instruments were tested in the Bureau's wind tunnels at speeds up to 180 miles per hour. These consisted of cup-and-propeller-type anemometers used in meteorological work and pitot tubes, vane anemometers, and thermal-type anemometers for general-purpose work such as the measurement of air flow in heating and ventilating systems. Eight microphones were calibrated to be used by other laboratories as secondary standards for the absolute measurement of sound pressure.

The range over which high-pressure manometers can be calibrated is being extended in response to increasing demands from industry for pressure calibrations above 10,000 lb per sq in. To this end a mercury manometer is being constructed as a fundamental standard to cover, for the present, the range up to 30,000 lb per sq in., and a piston gage of improved characteristics for use as a working standard is being designed to go to 100,000 lb per sq in. One-point portable pressure standards are to be set up, based on the change of state of certain substances such as water, at 30,000, 50,000 and 90,000 lb per sq in.

Organic and Fibrous Materials

During the fiscal year, 41,551 separate determinations were made on 13,716 samples of products containing organic and fibrous materials. This is a substantial increase over the 33,307 determinations made on 9,085 samples the previous year. Products tested included paper, twine, rope, rubber footwear, pneumatic tires, glue, hospital sheeting, tile flooring, carpets, mail bags, safety helmets, and plastic materials.

Three new standard samples for rubber compounding were established in addition to the four standard samples established during fiscal year 1948. Approximately 2,500 packages of these 7 materials, which are used in synthetic rubber plants for specification testing of production, were sold to the rubber industry during the past year. They are also used in the 13 standard synthetic-rubber formulas developed by a special subcommittee of ASTM Committee D–11.

A new lot of standard light-exposure paper was prepared. Booklets containing a supply of unexposed paper as well as a series of specimens exposed to known amounts of radiant energy in the Bureau's standard lamp were distributed to over 500 laboratories in the United States and foreign countries to standardize the exposure of their lamps. In a previous survey of the performance of such lamps, a variation of more than 200 percent in rate of exposure was found. It is anticipated that the standard light-exposure paper will enable different laboratories to control light exposure within a range of about 20 percent. The use of this paper for specification testing requiring light exposure is now being considered.

In connection with the Federal specifications for brushes, 80 master standards were established. They will be kept by the National Bureau of Standards and used to certify working standards for other Government agencies. These standards in turn will be used for comparison in acceptance testing of brush purchases.

Metallurgy

A total of 389 items were examined for quality of material and compliance with specifications. The largest item was 158 fusible plugs for marine boilers, examined for the U. S. Coast Guard. One hundred seventeen salt-spray tests were made, and 586 items were heat-treated for various Govern-

ment agencies. Two pressure vessels and one plunger made of 18:8 stainless steel were examined for the Geophysical Laboratory to determine the cause of failure. The experimental foundry prepared 1,495 castings of aluminum alloys, copper alloys, cast iron, lead, tin, and special compositions for other Government agencies. Seven sets of the eight standard steels were supplied to other laboratories for use as standards in the determination of oxygen in steel. Miscellaneous services include rolling, forging, swaging, and wire drawing of metals and metallographic and X-ray diffraction examinations.

Mineral Products

During the fiscal year, 124,813 separate determinations were made on 32,178 test items. Materials tested included glass, refractories, cement, concrete and concreting materials, soils, lime and gypsum, enameled metals, building stone, miscellaneous structural materials, and samples of minerals. By far the largest testing program was that on cement purchased for use on government construction projects.

Building Technology

The testing of building materials, construction, and equipment for conformance to specifications was an important activity of the Division. Test specimens included brick, tile, clay and concrete pipe, waterproofing materials, thermal insulation, and prefabricated assemblies of wall, floor, and roof constructions. In addition, 2,083 samples of bituminous materials were examined to provide information essential for the control of the quality of highway surfacings.

Photoflash bulbs submitted by the Civil Aeronautics Board were tested in order to standardize methods of packaging this commodity for safe air transport. Many items submitted by the U. S. Coast Guard, such as signal flares, distress signals, and smoke bombs, were type-tested for reliability and for fire safety with a view to certification as lifeboat and emergency equipment. Type tests were also made on numerous items of ships stores.

Performance tests were made on a baseboard convector for home heating and on a self-contained heater using alcohol as fuel and employing a steam turbine as a means for driving a ventilating air blower. A sludge solvent and a soot remover were analyzed, and their probable effectiveness was estimated. Five drinking-water coolers were tested for compliance with specifications as a basis for contract award by the Bureau of Federal Supply. The resistance to air flow, the efficiency, and the dust-holding capacity of four types of air filters were determined, and 24 specimens of porous concrete were examined to ascertain whether they are sufficiently permeable for use in the construction of grain-storage bins. In cooperation with a member of the American Academy of Allergy, an investigation was made to determine the

In addition to working out adequate methods for testing the ruggedness of electron tubes (p. 59), the Bureau is developing new kinds of rugged tubes. An X-ray photograph illustrates the essential structural superiority of ruggedized tubes—compare the heavy, rigid arrangement at right with the narrow, weak design at left.

ability of a dry-type and a glass-fiber throw-away-type air filter to remove grains of ragweed pollen from air.

A program carried on in cooperation with the American Society of Heating and Ventilating Engineers to determine the reliability of thermal conductivity measurements in different laboratories was nearly completed. Other thermal conductivity measurements included 28 calibration tests of heat-flow meters for governmental agencies and industrial firms; 31 tests of the conductivity of concrete samples both dry and after exposure to a constant humidity; 64 tests of insulating materials for Government agencies; and 18 tests for industrial and university organizations.

Electronics

Various types of electronic equipment and components were tested and calibrated for other Government agencies. An example is the testing of electron tubes. Specially designed, highly accurate, and extremely flexible equipment has been installed for measuring the characteristics of a wide variety of tubes, ranging in size from subminiature types to large power tubes and ranging in frequency from direct-current to microwave. Typical of the tests conducted during the year were (1) determination of the conformance of tubes to specifications, (2) evaluation of the suitability of tubes for special circuit applications, (3) examination and evaluation of tubes in electronic equipment which had failed or deteriorated, (4) measurement of the static curves of vacuum tubes in the positive grid region, (5) measurement of characteristics of tubes operating under nonstandard conditions, (6) evaluation of sample tubes which had been subjected to high-impact shocks and to conditions of extreme vibration, and (7) evaluation of foreign-made tubes and determination of their characteristics.

Radio Propagation

Instruments and deviees tested ineluded attenuators, cable, coils, diathermy generators, field-intensity meters, an impedance meter, insulating materials, a phase shifter, printed resistors, quartz-crystal units, radio receivers, radio-frequency voltmeters, slotted lines, and voltage generators. Standard frequencies and standard time signals were broadcast continuously from the Bureau's radio station WWV for use in the ealibration and test of frequency and time standards by the armed services, researeh laboratories, and various industries. To further the study of proposals for increasing the service area of these broadcasts, a new experimental standard frequency station (WWVH) was established on the island of Maui, Territory of Hawaii. Frequeneies on broadcast from both stations were accurate to 2 parts in 100 million. Continuous services from the new station began on November 22, 1948. Numerous reports on reception indicate that simultaneous operation of the two stations has caused no degradation and that many aretie and Pacifie areas are now eonsistently reeeiving standard frequencies for the first time. The services are widely used by industries such as mining, shipping, railroads, power, air transportation, communications, musical instrument manufacturers, and many others.

17. Technical Services and Cooperation

The Bureau's consulting and advisory aetivities for other Government agencies arise from the broad scope of its program in the physieal seienees and mathematics, its wide range of faeilities, and expert staff. Since other branches of the Government as well as industry rely on the Bureau for extensive ealibration and test work, the Bureau has taken a leading part in the development of improved methods for testing materials and equipment, in determining the physical properties and physical constants of an immense variety of materials, and in the study of teehnical processes. As a result, members of the Bureau staff are ealled upon by Federal ageneies to act as consultants in a great number of fields; where experimental work is required, the necessary faeilities are usually available at the Bureau.

The Bureau provides calibration serviees not only to the Fcderal Government but to State and municipal governments, universities, industry and private laboratories. In addition, the Bureau offers a program of assistance to State and local departments of weights and measures, coordinating their efforts and advising them on technical matters. The Bureau also cooperates extensively with teehnical and tradc groups, on a national basis, where the interests of the Government arc involved. Such cooperation is not only of value to the Government but provides a means of disseminating the results of Bureau work to the Nation in a direct fashion.

The National Bureau of Standards is the teehnical spokesman for the United States on international agreements relating to the development and establishment of international scientific standards and the establishment of

values for scientific constants. It is thus active in such groups as the International Union of Chemistry, International Telecommunications Conference, International Commission on Radiological Units, International Commission on Radiation Protection, International Commission on Illumination, and International Commission for Uniform Methods of Sugar Analysis. Another phase of international cooperation involves a program whereby scientists or diplomatic representatives from other countries are accepted at the Bureau as guest workers or visitors. Both aspects, which are important to the United States in terms of commerce and trade as well as the international policies of Government, are coordinated on the diplomatic level by the State Department.

Advisory Services

Advisory and consulting services are rendered to all agencies of the Federal Government, as well as many State and municipal governments. Agencies assisted during the year included the Departments of the Army, Navy, and Air Force; State Department; Department of Agriculture; Post Office Department; Atomic Energy Commission; Federal Communications Commission; Civil Aeronautics Board; Federal Trade Commission; Interstate Commerce Commission; Library of Congress; U. S. Capitol; Joint Chiefs of Staff; Veterans Administration; National Capital Parks and Planning Commission; American Battle Monuments Commission; National Park Service; Bureau of Engraving and Printing; Federal Housing Administration; Housing and Home Finance Agency; Joint Committee of Congress on Printing; U. S. Maritime Commission; Office of Rubber Reserve; Public Roads Administration; Federal Prison Industries; Bureau of the Mint; Customs Bureau; Army and Navy Munitions Board; Panama Canal; U. S. Tariff Commission; Office of International Trade; Bureau of Indian Affairs; U. S. Bureau of Mines; Social Security Administration; Bureau of Foreign and Domestic Commerce; Civil Aeronautics Administration; Bureau of

NBS Electronic Position Indicator. This instrument was designed at the Bureau to determine the clearance between rotor and stator blades of propulsion turbines in the USS Coral Sea during actual operating conditions. At left is the channel-selector switch and one of the pick-ups; the other pick-up is shown at right.

Federal Supply; U. S. Coast Guard; Public Health Service; Public Buildings Administration.

Continuous and more extensive work is undertaken through various scientific and technical committees. The Bureau is represented on numerous committees, panels, and commissions of other Government agencies. These include the Research and Development Board of the National Military Establishment, the Federal Interdepartmental Safety Council, the Federal Fire Council, the Interdepartmental Radio Advisory Committee, the National Conference on Weights and Measures, the National Advisory Committee for Aeronautics, the Interdepartmental Committee on Photographic Papers and Films, the Interdepartmental Screw Thread Committee, the Interdepartmental Committee on Fire Tests of Cellulose-Nitrate Motion Picture Film Vaults, the Joint Committee on Unification of Building Codes, and a number of similar groups.

Federal Specifications

An important phase of the Bureau's work consists in cooperation with the Federal Specifications Board and other standardizing agencies in the development and improvement of specifications. To avoid duplication of effort in Government procurement, the Federal Specifications Board compiles and adopts specifications for the purchase of supplies by the Federal Government. These specifications result in purchase economies by establishing criteria which guarantee quality and by providing an opportunity for all businesses to compete for Federal trade through the bid system. Under the chairmanship of the Director of the National Bureau of Standards and in cooperation with the Bureau of Federal Supply, the Board discharges its functions through 76 technical committees. A total of 156 positions on these committees, including 52 chairmanships or other offices, are filled by specialists of the Bureau's staff. Considerable experimental investigation is carried on at the Bureau in the development of test methods, which are so often indispensable before a specification can be framed or applied. Other laboratory studies become necessary in connection with the continual revision of the specifications to keep them abreast of industrial practice and the changing needs of the Government. More than 2,000 Federal specifications are now in effect.

Mathematical Problems

One of the primary functions of the Bureau's Applied Mathematics Division has been the furnishing of mathematical services to various Federal agencies. These services consist mainly of (1) computing services in connection with specific problems in applied mathematics and (2) consultation services on the applications of mathematical statistics.

Typical of the first type of work was the solution of complicated systems of simultaneous nonlinear equations describing shock waves which follow an

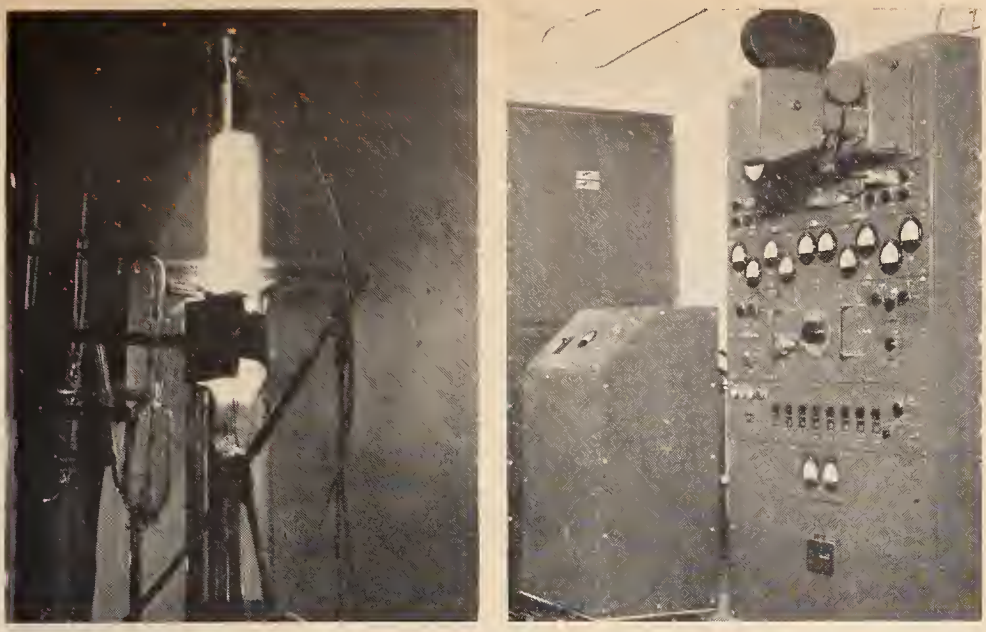
explosion. This was done for the Bureau of Ordnance, Department of the Navy. Tables and graphs of certain functions which facilitated the solution were prepared. The ultimate purpose of the computations was the prediction of the performance of explosives of various chemical composition.

An outstanding example of the application of computing techniques to the science of management is found in a problem now in process of solution for the Air Comptroller's Office. The object of the problem is to devise a purely mechanical process which may be used to replace the thousands of individual human decisions involved in a major management program. For example, in achieving a given volume of production or in deploying a certain number of troops and equipment at a given date, it is necessary to procure machines, transportation, materials and supplies, spare parts, and fuel and to provide for the training of operating and supervisory personnel. The personnel requirements in the levels of activity involved at each step have hitherto been the subject of a multitude of separate decisions arrived at by "educated guessing" on the part of different individuals. The present project aims to develop methods of replacing these decisions by high-speed mathematical computation. Methods are being tried out using the most up-to-date computing equipment available, and further methods will be tested as better and faster computing machines become available in the future.

The Johns Hopkins University is conducting for the Operational Research Office, Department of the Army, a study to determine the physiological effects of exposure to nuclear radiation. The results will be used to set safety limits and dosages to which workers and military personnel may be exposed. Because of the obvious difficulty of experimenting with human beings, experimental material obtained from test animals is used. In connection with this work, the Bureau was asked to compute the life expectancies for animals subjected to various dosages of various types of radiations and to compare them statistically with the normal life expectancies of unexposed animals. Theories regarding ionization in body tissues caused by radiation were also evaluated numerically at the Bureau, and the results are compared statistically with experimental results.

Building Technology

The Bureau provided assistance to other Government agencies on a wide range of technical problems relating to building constructions and equipment and to fire and other hazards to life and property. For example, the Public Buildings Service requested the National Bureau of Standards to make tests and inspections in connection with the proposed remodeling of the White House. Members of the Bureau staff installed strain gage points and made readings to show the nature and extent of movements of the masonry. Samples of the masonry materials were tested, and the results of the tests were interpreted for the engineers responsible for the plans for renovation.



Left: special helium-filled arc discharge tube used by the Bureau in a study of the problem of gas disappearance in electron tubes filled with a noble gas (p. 59). An automatic ionosphere recorder (right), designed by the National Bureau of Standards, is used at the Bureau's Belvoir Field Station to gather ionospheric data which will aid in predicting radio disturbances (p. 70).

Assistance was given to Federal agencies on many problems of heating and air conditioning. Thus, the Bureau was consulted on the testing of the heating system for the Lustron house, and recommendations for the design of the heating system were prepared. Test data and opinions were furnished to the Quartermaster General on Army field-cooking, refrigerating, and heating equipment and to the Federal Trade Commission on fuel oil additives and soot removers. Other agencies obtained data and advice pertaining to the removal of airborne dust and bacteria, apparatus for heat-transfer measurements, grain dryers, refrigeration systems, and heating equipment.

Numerous requests were also received for advice on roofing, waterproofing, and related problems. Warehouse roofs at the Quartermaster General Depot at Columbus, Ohio, were inspected for the Department of the Army in an attempt to settle a controversy over responsibility for roof repairs where the roofs were covered by a surety bond. Other requests were of a more general nature, dealing with such questions as that of suitable roofing materials on structures in Alaska or the acceptability of new roofing, waterproofing, or siding materials under the requirements of the Federal Housing Administration.

The Bureau continued to cooperate with the Interagency Committee on the Texas City Disaster, the Interdepartmental Committee on the Storage of Motion Picture Film, and the Federal Fire Council. Assistance was rendered in determining the explosive properties of ammonium nitrate and inert filler at high temperatures. Tests with the motion picture film

storage vault were continued, and information thus obtained was made available to governmental agencies concerned with the storage of nitrate film.

Organic and Fibrous Materials

Over 50 Federal agencies were assisted in problems pertaining to natural and synthetic rubbers, textiles, paper, leather, and organic plastics. For example, the Office of the Quartermaster General sought advice and assistance from the Bureau in the retreating and reconditioning of shoes, athletic equipment, and other leather products. Fungicidal treatments were developed and retreatment procedures were recommended for items now being salvaged and stored. As a result, about 1,000,000 pairs of shoes will be retreated this year, and about 90 carloads of mildewed athletic equipment will be reconditioned and stored. The total savings on these two items is estimated at $5,000,000.

In another instance, the properties of various plastic insect screens in commercial production were evaluated at the request of several Government agencies to obtain data for a Federal specification for procurement purposes. Results of laboratory tests at the Bureau and actual behavior in service showed that screen woven of monofilaments of saran plastic is equal to or superior to bronze screen in most applications. Since plastic insect screen costs about 20 percent less than bronze screen, the use of plastic screen will result in considerable savings to the Government.

In cooperation with the Federal Housing Administration and the Housing and Home Finance Agency, a study was made of various materials for water vapor barriers. With the advent of tighter building constructions for conservation of fuel and the increasing use of air conditioning, effective vapor barriers are required to prevent condensation of moisture between walls and in other parts of structures. This study resulted in the establishment of standards for vapor barriers used in regulations for new housing construction.

Mineral Products

Requests for technical assistance in the general field of nonmetallic inorganic mineral products came from a number of different agencies. Consultation services were rendered to the National Capital Parks, the Federal Bureau of Supplies, the Public Buildings Administration, the Panama Canal, the American Battle Monument Commission, the U. S. Bureau of Mines, the Army Corps of Engineers, the Federal Power Commission, and the Office of the Quartermaster General in matters concerning the use, preservation, and protection of structural stone. Included were such problems as the repair of the White House, the preservation of battle monuments, and the selection of grave markers. The state of Virginia was aided in determining the cause of damaging expansion taking place in the interior partitions of the Virginia

State Historical Library. Assistance was given the Army, Navy, Air Force, National Advisory Committee for Aeronautics, and the Research and Development Board on procurement and specifications for large optical elements for use with wind tunnels and aerial cameras, and on ceramic coatings for metals for high-temperature installations.

Consultative services for the Atomic Energy Commission took the form of two classified surveys to provide ceramic information necessary for the utilization of atomic energy, and consultation with the Geological Survey concerning the source and characteristics of fissionable raw materials. The Bureau of Yards and Docks, Department of the Navy, was aided, through consultation and field examination, in determining the cause and possible prevention of expansion in concrete dry docks. In addition, the Bureau actively participated in the work of the Federal Specifications Board in connection with the introduction and revision of specifications on whitewares, glass, porcelain-enameled tile, photographic graduates, X-ray processing tanks, and portland cement.

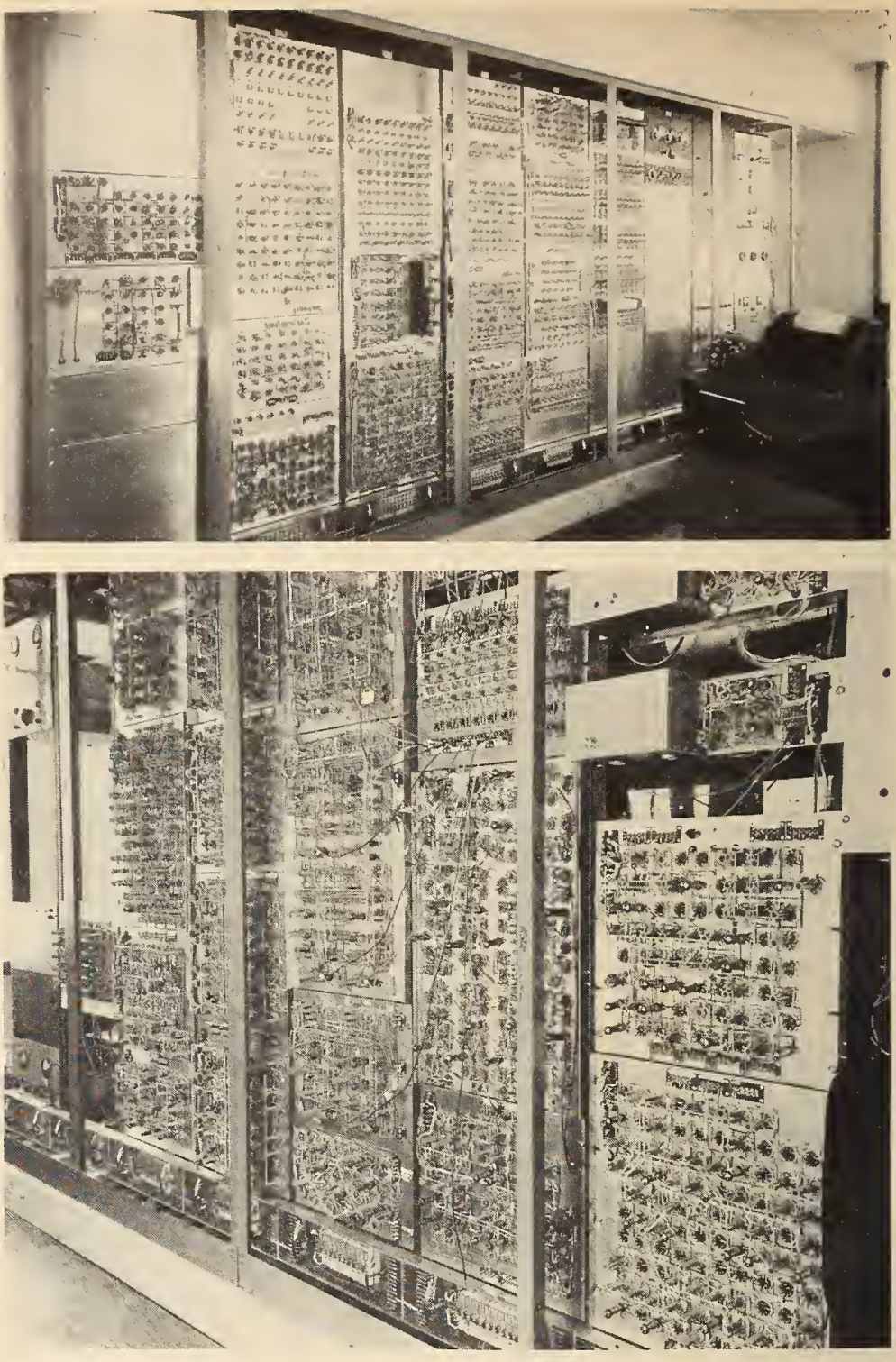
Commodity Standards

The Commodity Standards Division acts as a secretariat for industry and trade groups desiring quantitative or qualitative standards. Through formulation of Simplified Practice Recommendations for sizes and varieties of manufactured products, it aids specific industries in the development of voluntary programs for the elimination of avoidable waste. It also cooperates with organizations of manufacturers, distributors, and consumers in the development of voluntary Commercial Standards, which encourage fair competition through the standardization of methods for testing, rating, certification, and labeling of commodities.

Work of the Division involves collection and analysis of the necessary data as well as the actual formulation of the standard for acceptance by the organizations concerned. Much of the data utilized in the preparation of the standards results from the research and testing activities of the other divisions of the Bureau.

Twelve Simplified Practice Recommendations were issued during the fiscal year. Of these, 2 were new while 10 were revised or reissued. The 2 new recommendations deal with delivery cases for square milk bottles and the packing, loading, and marking of steel products for overseas shipments. Eight new Simplified Practice Recommendations are now in process of development, and 21 are currently undergoing revision.

Sixteen Commercial Standards were issued, of which 10 were revisions of previous standards. The 6 new standards covered wire rope (exports), copper naphthenate wood preservative, colors for polystyrene plastics, ponderosa pine and sugar pine plywood, model forms for girls' apparel, and sun-glass lenses made of ground and polished plate. Forty-three new Commercial Standards are currently being developed, and 30 others are at present undergoing revision.



The nearly completed National Bureau of Standards Eastern Automatic Computer (p. 63). Central portion of the machine, showing teletype for transmitting instructors to the computer (above). Input-output and electrostatic memory circuits (below). A second computer, the NBS Western Automatic Computer, is under construction at the NBS Institute for Numerical Analysis in Los Angeles.

Weights and Measures

While the National Bureau of Standards is the custodian of the Nation's standards of length and mass, the Congress has left to the control of the individual States the regulation of commercial weighing and measuring devices and operations. As the Bureau has no regulatory authority over the weights and measures activities of the States, it functions only in an advisory and coordinating capacity in this field.

The translation of the basic standards of length and mass and of the derived standards of capacity to the channels of industry and trade is a matter of great economic importance to the producing, manufacturing, processing, and distributing agencies in this country and to all purchasers of commodities. To aid in this work, the Bureau established late in 1947 an Office of Weights and Measures whose over-all function is to promote the extension, raise the standard of efficiency and coverage, and increase the degree of uniformity of State weights and measures supervision throughout the United States. A definite program of assistance to State and local departments of weights and measures as well as to business and industry has been set up and successfully pursued. During the past year recognition of the importance of such work and the demand for assistance and advice in this field have continued to increase.

A large part of the activity of the Office of Weights and Measures consists of consultative services rendered through correspondence; through visits to the office by representatives of Federal agencies, business and manufacturing concerns, and weights and measures officials; and through visits of members of the office to weights and measures officials in their own jurisdiction. The field of inquiries is broad, embracing the drafting of new legislation; the interpretation of laws, specifications, tolerances, and regulations; the design of testing equipment; methods of test of commercial equipment; the reporting of activities in different weights and measures jurisdictions; problems of and plans for weights and measures administration; planning and conducting weights and measures conferences; training schools for State departments; and the like.

A major medium of cooperation with weights and measures officials, manufacturers of weighing and measuring devices, and associated interests is the National Conference on Weights and Measures. The thirty-fourth meeting of this organization was held in Washington in May 1949, under the sponsorship of the National Bureau of Standards. The official registration of 292 included 160 weights and measures officials from 34 States and the District of Columbia, 109 representatives of business and industry, and 21 persons from Federal agencies.

As secretary of the conference, the Chief of the Bureau's Office of Weights and Measures is responsible for planning and conducting the meetings. He is also a member of the Committee on Specifications and Tolerances, one of the more important standing committees of the conference, which is charged with the development of the technical requirements for commercial

weighing and measuring devices. The Bureau has been active in the work of this committee, whose recommendations lead to the technical requirements promulgated by the States. This year the Conference adopted without change the recommendations of the committee for a complete revision of the handbook entitled *Specifications, Tolerances, and Regulations for Commercial Weighing and Measuring Devices.* The revised material is being published as a new handbook, which will be recommended for promulgation by the States as the legal technical requirements for the various jurisdictions.

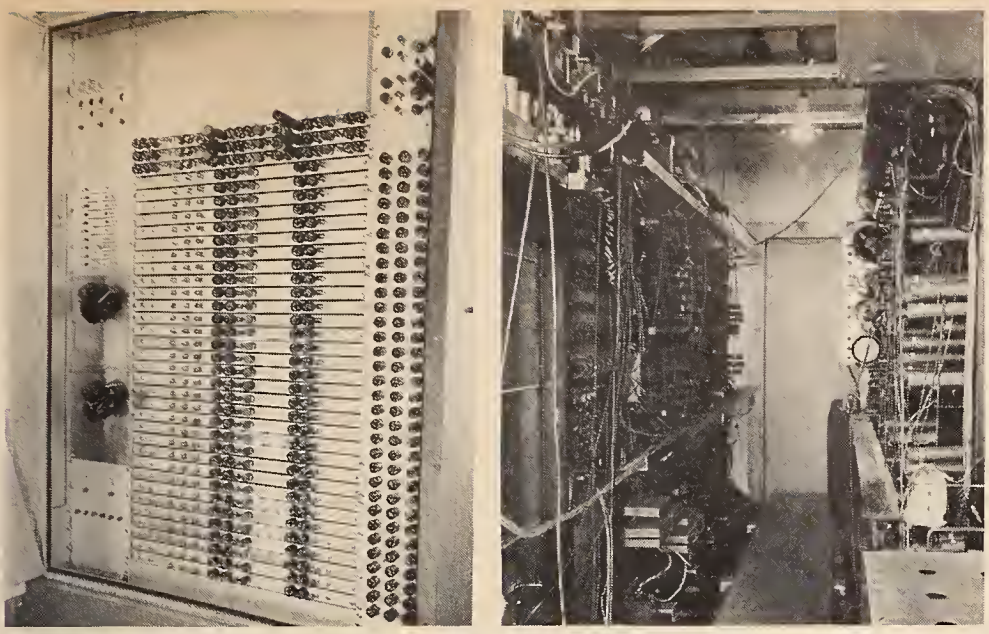
Another important standing committee of the conference is the Committee on Weights and Measures Education, which sponsors and encourages weights and measures education at all levels throughout the United States. The Office of Weights and Measures is represented on this committee by its assistant chief, who serves as secretary to the committee.

The Chief of the Office of Weights and Measures is also chairman of the Technical Committee on Weighing and Measuring Devices of the Federal Specifications Board, which has been active during the year in developing specifications for scales and balances. The assistant chief of the office is an alternate member of this committee.

Research Associate Program

The research associate plan is an arrangement under which technical, industrial, and commercial organizations can support work at the Bureau on projects which are of special interest to them, yet of sufficient general interest to justify use of Government facilities. Research associate projects must not only be of value to all groups concerned in the particular field and to the Federal Government, but must also be important from the standpoint of the Nation's sum total of technologic knowledge. While the arrangement is preferably made with an association or group representing a major part of the industry concerned, projects may be undertaken in cooperation with single companies or individuals when the results may be expected to be of value to the general public. In any case, the results become a part of the public domain and are published by the Bureau. Research workers acceptable to both parties are either assigned by the Bureau or employed by the supporting organization, which pays their salaries and other expenses incident to the project.

Since the research associate plan was established in 1920, more than 175 organizations and individuals have supported cooperative research at the Bureau. Many of the projects have been extremely specific and therefore of relatively short duration. Others, such as that supported by the Portland Cement Association, have been directed toward fundamental research in the field; this project has been active since 1924. The American Petroleum Institute has a total of 36 research associates in two projects, one of which has been in operation continuously since 1927. The project spon-



The internal high-speed memory (left) of the NBS Eastern Automatic Computer (p. 63) stores orders to the computer, the numbers involved in a problem, and the results of intermediate computations. Right: interior, showing the many small electronic components.

sored by the American Dental Association has been in existence since 1930, and that sponsored by the Cast-Iron Pipe Research Association has been active since 1928.

At the close of the fiscal year 13 groups were supporting 72 research associates at the Bureau. Cooperative projects were under way on dental materials, fuels, commercial adsorbents, electrodeposition, corn products, hydrocarbons, underground corrosion, cement, conerete, standards for X-ray diffraction analysis, chinaware, porcelain enamel, and asphalt roofing.

Scientific and Technical Groups

Through active participation in the projects of professional societies and standardizing bodies, the Bureau plays an important part in the development of test methods and criteria, in the application of scientific discoveries, and in fundamental research programs of a national nature. It thus aids in developing and improving engineering standards, purchase specifications, and building and safety codes. Bureau staff members now hold approximately 1,600 positions on committees of over 90 national groups such as the American Society for Testing Materials, American Standards Association, American Society of Textile Chemists and Colorists, American Ceramic Society, American Concrete Institute, American Foundrymen's Association, American Geophysical Union, American Institute of Electrical Engineers, American Petroleum Institute, American Socicty of Heating and Ventilating Engineers, American Society of Mechanical Engineers, Institute

of Radio Engineers, Instrument Society of America, Inter-Society Color Council, National Fire Protection Association, Optical Society of America, Radio Manufacturers Association, Society of Automotive Engineers, and Society of Motion Picture Engineers.

During the year, the adequacy of a newly developed shutter for moving stairways to hold back fire was investigated at the joint request of the Buildings Officials Conference of America and the National Fire Protection Association; technical data and drafts of specifications were furnished to Federal Specification and ASTM technical committees on such subjects as clay brick and tile, asbestos-cement building products, bituminous roofing materials, electrical refrigerators, mechanical water coolers, and air-conditioning equipment; a report on fire hazards of domestic chimneys was made to the National Fire Protection Association and another on their draft characteristics to the American Society of Heating and Ventilating Engineers; the American Society for Testing Materials was assisted in developing standard methods for determining the abrasion resistance of woven textiles, plastics, rubber, carpets, and coated fabrics; the National Research Council was aided in the formulation of a research program for plastic materials and products, in a review of current projects on plastics, and in the development of improved military textiles and clothing; information essential to the preparation of a safety code for glazing motor vehicles on land highways was given the Society of Automotive Engineers; methods of evaluating the properties of plastic films and sheeting were developed for the Society of Plastic Industry; the American Association of Textile Chemists and Colorists was assisted in the development of standard methods for determining flammability, color-fastness, and water-repellency of textiles; the American Leather Chemists Association was aided in the development of test methods for fire resistance, bursting strength, water absorption, water-vapor permeability, and resistance to scuffing of leather and leather products; the American Standards Association was given data for the formulation of performance standards for nylon hosiery; the Technical Association of the Pulp and Paper Industry was aided in the development of methods for testing paper; the Society of Motion Picture Engineers was assisted in a study of storage and preservation of films and stability of color films; the metering of gases flowing in commercial pipelines was studied for the American Gas Association and the American Society of Mechanical Engineers; and cooperative services were supplied to the Applied Physics Laboratory of Johns Hopkins University in connection with the use of rockets for stratospheric exploration.

International Radio Conferences

The prominent position occupied by this country in world affairs has required it to play a leading part in the work of the International Telecommunications Union, which allocates radio frequencies among the nations. During the past year, the Bureau supplied scientific and technical advisors

for the American delegations to conferences sponsored by the Union as follows: Provisional Frequency Board, Geneva, Switzerland; World Aeronautic Radio Conference, Geneva, Switzerland; International Radio Consultative Conference, Stockholm, Sweden; High-Frequency Broadcasting Conference, Mexico City; Fourth Inter-American Radio Conference, Washington, D. C. In addition to actual participation in the deliberations of these conferences, a large supporting program was maintained in the Bureau's laboratories to supply the technical advisors with the information they required.

International Commission on Illumination

A member of the Bureau staff served as delegate to the meeting of the International Commission on Illumination held in Paris in June and July 1948. Bureau staff members now serve as secretary of the U. S. National Committee, which represents the Commission in this country; secretariat director of the Committee on Colorimetry and Artificial Daylight; chairmen of the U. S. Committees on Aviation Ground and Airport Lighting, Units, and Standards and on Calculation of Projector Systems; U. S. representatives on the Committees on Physical Photometry, Ultraviolet Radiation, Traffic Signals, and Visual Photometry; and secretary and member of the ad hoc Committee on Color Specifications for Light Signals.

International Conference on Weights and Measures

At the Ninth General Conference on Weights and Measures, held in Paris October 12 to 21, 1948, the Director and an Associate Director of the Bureau represented the United States through appointment by the Department of State. The most important technical development of the Conference was the adoption of a revised text describing the International Temperature Scale. A translation of this text has since been published in the National Bureau of Standards Journal of Research. The Conference also recognized formally the possibility that the basic unit of length, the meter, might eventually be defined by reference to a wavelength of light. One of the most promising wavelengths for this purpose is that of the green line of mercury 198, an artificial isotope transmuted from gold by neutron bombardment.

Office of International Relations

Scientists and engineers from other countries are permitted to participate in certain normal work of the Bureau as guest workers. The program is conducted under procedures of the Department of Commerce and the Department of State, in accord with such legislation as the Fulbright Act (Public Law 584, 79th Cong.) and the Smith-Mundt bill (Public Law 402, 80th Cong.). The Bureau's Office of International Relations makes arrangements for foreign scientists to be accorded guest privileges at the

Bureau; receives official visitors from abroad; correlates Bureau activities with those of other Federal committees handling international relations, and assists the Bureau in its own representation abroad at international meetings. Such a program not only strengthens the relations of this country with other nations but also permits the Bureau to keep more closely in touch with foreign developments and provides it with additional expert temporary staff associates.

During the last year the total number of visitors and guests from other countries was 533. Eight directors of research institutions analogous to the National Bureau of Standards were among them, representing Belgium, Italy, China, Sweden, Mexico, Chile, India, and Great Britain. Other visitors included 21 directors of specialized research institutions, 125 research scientists and engineers, 63 university professors, 70 government officials, 81 industrial engineers, and 3 delegations consisting of 23 individuals. In addition, 46 scientists and engineers were accepted for programs ranging from 3 to 12 months in duration, as well as 10 trainees sponsored and supported by the Department of State and 63 technical students of graduate level.

Technical Session on Bone Char Research

The first technical Session on Bone Char Research was held on January 27 and 28, 1949, at the National Bureau of Standards in Washington, D. C. Conducted jointly by the Bureau and the industrial sponsors of its work in this field, the session was attended by representatives of sugar refiners and bone char manufacturers in Canada, England, Scotland, and the United States. Only those sponsors in Australia and South Africa were unable to send delegates.

Fourteen formal papers presented as many aspects of the problems of the industry, and discussion periods following each presentation provided opportunity for exchange of ideas on many technical questions relating to refinery operation. One-half day was devoted to each of the following subjects: bone char kilns, test procedures, filtration operations, and basic research on the properties of bone char.

Approximately 9,000,000,000 pounds of raw cane sugar are refined annually in the United States, requiring the use of roughly half this weight of bone char. Since this is obviously many times the amount of bone char in stock, the success of the bone char process depends largely upon the efficiency with which the char can be revivified so that it can be used many times. Prior to 1939, detailed basic knowledge of the bone char process in sugar refining was very meager. To fill this need, a research program was initiated at the National Bureau of Standards for study of the fundamental nature of bone char and other solid adsorbents. Interest in the project has steadily increased until today industrial supporters of this work include almost all of the cane sugar refiners and bone char manu-

facturers of the United States as well as those in Canada, England, Australia, and South Africa. Research which cannot conveniently be undertaken by any one of the cooperating sponsors is conducted in the laboratories of the Bureau while problems requiring plant facilities for their solution are studied in a number of individual refineries. The purpose of the Technical Session held at the Bureau was to inform the industry of the present status of the research program and to permit informal discussion of problems of mutual interest.

E. U. Condon,
Director, National Bureau of Standards.

SCIENTIFIC AND TECHNICAL DIVISIONS AND SECTIONS

ELECTRICITY AND OPTICS

Resistance Measurements
Inductance and Capacitance
Electrical Instruments
Magnetic Measurements
Photometry and Colorimetry
Optical Instruments
Photographic Technology
Electrochemistry

METROLOGY

Length
Mass
Time
Capacity, Density, and Fluid Meters
Thermal Expansion
Dental Materials
Scales
Gages

HEAT AND POWER

Temperature Measurements
Thermodynamics
Cryogenics
Engines and Lubrication
Engine Fuels
Combustion

ATOMIC AND RADIATION PHYSICS

ATOMIC PHYSICS

Spectroscopy
Radiometry
Mass Spectrometry
Physical Electronics
Electron Physics
Atomic Physics
Neutron Measurements

RADIATION PHYSICS

Nuclear Physics
Radioactivity
X-Rays
Betatron
Nucleonic Instrumentation
Radiological Equipment

CHEMISTRY

Paint, Varnish and Lacquer
Surface Chemistry
Organic Chemistry
Analytical Chemistry
Platinum Metals and Pure Substances
Electrodeposition
Gas Chemistry
Physical Chemistry
Thermochemistry and Hydrocarbons
Spectrochemistry

MECHANICS

Sound
Mechanical Instruments
Aerodynamics
Engineering Mechanics
Hydraulics

ORGANIC AND FIBROUS MATERIALS

Rubber
Textiles
Paper
Leather
Testing and Specifications
Organic Plastics

METALLURGY

Optical Metallurgy
Thermal Metallurgy
Mechanical Metallurgy
Chemical Metallurgy
Experimental Foundry
Underground Corrosion

MINERAL PRODUCTS

Porcelain and Pottery
Glass
Refractories
Enameled Metals
Building Stone
Concreting Materials
Constitution and Microstructure
Chemistry of Mineral Products

BUILDING TECHNOLOGY

Structural Engineering
Fire Protection
Heating and Air Conditioning
Exterior and Interior Coverings
Codes and Specifications

APPLIED MATHEMATICS

Numerical Analysis
Computation
Statistical Engineering
Machine Development

COMMODITY STANDARDS

Metal and Ceramic Products
Textiles and Apparel
Mechanical Equipment
Packaging
Chemical Products

ELECTRONICS AND ORDNANCE

ELECTRONICS STANDARDS

Engineering Electronics
Electron Tubes
Electronic Computers

ORDNANCE DEVELOPMENT

Ordnance Research
Ordnance Mechanics
Ordnance Electronics
Ordnance Engineering
Ordnance Tests

GUIDED MISSILES

Missile Dynamics
Missile Intelligence
Missile Engineering
Missile Instrumentation
Technical Services

CENTRAL RADIO PROPAGATION LABORATORY

IONOSPHERIC RESEARCH

Upper Atmosphere Research
Ionospheric Research
Field Operations

SYSTEMS RESEARCH

Regular Propagation Services
Frequency Utilization Research
Tropospheric Propagation Research

MEASUREMENT STANDARDS

High Frequency Standards
Microwave Standards